METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

October, 1936. Vol. XIV., No. 84.

The Problem of Efficient Enamelling of Light Alloy Components of the Magnesium-Base Type

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The increasing use of light alloy components has directed attention to the development of suitable finishes. With magnesium alloys special consideration of the preliminary surface treatment is necessary as well as the nature of priming coats. In this article the author gives practical details of various finishing schemes for miscellaneous magnesium alloy components. Various combinations, simple and complex, are investigated and rational recommendations made from the conclusions drawn.

MAGNESIUM has gradually impressed itself upon the engineering world as a constructional material of prime importance in an unassuming manner during the past ten to twenty years. The names Electron and Dow-metal widely recognised on the Continent and in America, respectively, are not so universally recognised in this country, where specifications for magnesium alloys are extensively used, the chief, of course, being the D.T.D. series compiled by the Air Ministry. Lightness is the salient feature attracting attention to the magnesium alloys, density being only approximately two-thirds of that of aluminium. It is natural, therefore, that aircraft and automobile construction have absorbed the major portion of these alloys, but numerous accessories, radio receivers and transmitters, direction finders, and other instruments are also utilising them, while useful extensions to other spheres of engineering are forcing the attention of metal-finishing departments to suitable treatments for miscellaneous components. The latter include castings, pressings and articles machined from sheet and rod. While, in general, it may be stated that the usual finishing technique applies, some special consideration is called for with respect to preliminary surface treatment as well as with regard to the nature of priming coats. Organic films of lacquer or enamel are usual, electroplate coatings apparently not yet having been commercialised.

The intricacies associated with finishing magnesium alloys with effective, durable coatings have their origin in the electro-chemical nature of magnesium. This metal is highly electro-positive, in fact, it is the most electro-positive of the metals employed in engineering. Its electrode potential is + 1·3 volts as compared with + 1·0 for aluminium, + 0·5 for zinc and + 0·2 for iron on the positive side, and − 0·1 for lead and tin, and − 0·6 for copper and brass on the negative side. These values predict that the propensities of magnesium towards corrosion in moist atmospheres, as well as under less favourable conditions when slightly acidic constituents are present, carbon dioxide, sulphurous products, etc. will be markedly greater than is the case with zinc and iron. The position of aluminium is anomalous, because it forms a natural oxide film as an envelope over its surface, and, moreover, this skin is self-healing, and provides extensive protection under ordinary conditions. Unfortunately, magnesium presents no such tendency and this adds much to the troubles in the finishing shop. Technicians responsible for the latter, therefore, have to bear in mind that they are concerned with material which rapidly reacts with moisture, as well as with weak acidic bodies, and the following criteria must be safeguarded :—

1. The magnesium surface at the time of finishing must be clean and dry, otherwise reaction proceeds and, in effect, the first coating is applied to a "moving" surface.
2. The first coating must not contain highly acidic constituents which, during the drying period or subsequently, react chemically with the magnesium.
3. The coating must be continuous and applied in a sufficient number of applications so that pinholes or porosity are absent, otherwise moisture will penetrate and reaction at the metal/paint juncture will cause flaking or lifting of the coating.

All the magnesium-base alloys are similar with respect to activity under corroding conditions and hence with relation to finishing treatment. The alloying of 0·5 to 1·5% of manganese with magnesium appreciably reduces the rate of corrosion of the latter, but not sufficiently to take it out of the category of easily corroded metals. The alloys encountered in industry may contain up to 10% aluminium, up to 3·5% zinc, up to 1·5% manganese, small amounts of silicon and iron and traces of copper as impurities. Also, one series of American alloys contains from 4 to 7% of tin, as this facilitates forging by the hammer process ; it is not generally used in this country. All these alloys can be given the same consideration technically from the viewpoint of finishing.

In the following, practical details of various finishing schemes and test results are given to show how far the normal finishing media used in the average enamelling shop of a general engineering factory can be utilised for miscellaneous magnesium alloy components. Various combinations, simple and complex, are investigated and rational recommendations made from the conclusions drawn.

It has been remarked that magnesium alloys do not acquire a self-protective oxide film in the same way that those of aluminium do ; again, it does not respond to electro-anodic treatments. At the same time aqueous chromate solutions confer some degree of protection, these being somewhat similar to the M.B.V. treatment for aluminium. Castings are usually chromated by the manufacturers and thereby show considerably improved behaviour under transport and storage conditions. Processing in this manner is indispensable prior to enamelling, and more detailed reference is made to it below.

Degreasing and General Cleaning

Components for finishing will invariably be contaminated with machine lubricants, which may include mineral oils, cutting oils proper, soluble oils, tallow or grease, and these

will carry with them swarfe or dirt. Solvent cleaning, trichlorethylene being the usual medium, is often sufficient, especially where liquor or liquor/vapour degreasers are available. But if swarfe contamination is prolific, or soap greases are present, hot alkali cleansing is to be preferred. A solution of sodium meta silicate (4 to 8 oz. per gallon) short of boiling is a good bath to employ, being very free-rinsing in a subsequent cold and hot-water wash. Another sound formula comprises 3 oz. soda ash, 2 oz. caustic soda and 1 oz. soap per gallon.

If the work is at all corroded, a controlled clean in cold 15 to 20% nitric acid is necessary.

TABLE I.

DATA DEMONSTRATING IMMUNITY OF MAGNESIUM ALLOYS FROM ATTACK BY SLOW CHROMATE TREATMENT.

Specimen immersed in gently boiling solution of ½ lb. sodium dichromate and ½ lb. potassium dichromate in 1 gal. of water for 1 hour.

Thickness Readings in Inches.

Reading No.	Before.	After.
1	0·0488	0·0488
2	0·0492	0·0491
3	0·0491	0·0491
4	0·0490	0·0491
5	0·0492	0·0494
6	0·0495	0·0504
7	0·0505	0·0505
8	0·0506	0·0507
9	0·0507	0·0508
10	0·0510	0·0507
11	0·0506	0·0505
12	0·0500	0·0499
13	0·0499	0·0499
14	0·0500	0·0499
15	0·0506	0·0507
Mean	0·0498	0·0498

Total weight loss of specimen	0·0070 grms.
Total area of specimen	39·0 sq. in.
Average decrease in thickness (calculated)	0·00002 in.

TABLE II.

COMPOSITIONAL DATA OF MAGNESIUM ALLOYS USED FOR TESTS ON VARIOUS FINISHES.

Material No.	1	2
Form	Castings	Sheets
Composition—	%	%
Aluminium	7·90	5·30
Manganese	0·33	0·37
Copper	0·12	Nil
Iron	0·05	0·02
Zinc	Absent	Absent
Lead	"	"
Silicon	"	0·02
Tin	"	Absent
Magnesium	Remainder	Remainder
Hardness, Vickers' Diamond Numerals	63	67

Chromate Treatment

A large number of suitable solutions have been mentioned in literature, and some of them appear to be covered by patent. Two typical formulations which have proved satisfactory, but of distinctly different type in their effect, are as under :—

A. Rapid Chromate Treatment.—The solution is prepared from 1½ lb. of sodium dichromate and 1½ pints of concentrated commercial nitric acid (S.G. 1·42) in a gallon of water. It may be used up to 150° F., with immersion times ranging from two minutes at ordinary temperature to half a minute at 150° F.

B. Slow Chromate Treatment.—The solution is prepared from ½ lb. of each sodium and potassium dichromates per gallon of water. It is employed gently boiling, and immersion time is from one to two hours. It is to be noted that no nitric acid is included in this make-up and therefore it does not attack the articles immersed. Hence, the longer period necessary but allowable, and this type of treatment is eminently suitable for components machined to close dimensional tolerances, + 0·0005 in. often being essential for assembly reasons. The attributes of the solution in this direction are amplified by the data given in Table No. 1, the material employed being that given in Table No. II, Sample No. 2.

Aluminium, eathenware or enamelled iron may be employed as containers for the chromate solution. After chromating, the articles are thoroughly washed in cold and hot water, and rapidly dried off by air blast, hot-air oven or sawdust. Losses of the chromate solution by evaporation must be made up by water addition, and retention of the nominal composition should be achieved by occasional analysis.

The visual result of the chromate treatment is in general a light golden yellow colouration of the surface, more marked with the rapid solution than with the slow one, but it may be irregular depending upon the surface and metallurgical condition of the alloy.

Organic Finishing

The chief industrial media, whether lacquer or enamel, are air-drying cellulose, air-drying oil, air-drying synthetic stoved oil or stoved synthetic. Cellulose finishes direct on magnesium alloys do not seem to be satisfactory, and therefore for mass handling, stoved-enamel finishes become essential because rarely can the long air-drying periods be allowed. Again, choice of first coating has a definite bearing upon the durability of the finish. Red oxide of iron and yellow zinc chromate primers both exhibit marked inhibiting properties, the chromate generally proving a little superior to the oxide commodity.

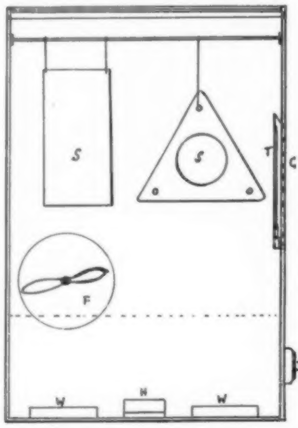


Fig. 1.—Section through humidity cabinet.

For testing the relative merits of a number of finishes, two types of base material were employed, castings and sheet, the compositions being given in Table II. Specimens were cleaned as above, and tested without chromate treatment, with rapid chromate and with slow chromate, in order to arrive at some firm final conclusions. Before submission to durability tests, cellulose enamelled samples were held for two weeks, and stoved specimens for two days. The durability exposure tests were of three types, which, respectively, could be regarded as of mild, moderate and rigorous severity—viz. :

(*a*) *Mildly Accelerated Conditions.*—A cabinet was arranged to simulate tropical conditions with only temperature and moisture fluctuations to accelerate attack. Temperature control was achieved by an electric heater H in the base of the chamber, with an external variable resistance R. Trays of water, W, provided humidity, the percentage being determined by temperature. Uniformity of atmosphere was maintained by a slow-moving fan F. Specimens S were centrally suspended above the perforated shelf D, out of direct radiation from the heaters. A diagrammatic view of the arrangement is given in Fig. 1. During the working day the temperature was adjusted to 135/140° F., at which a relatively dried atmosphere of 60% humidity was acquired. At night it was allowed to fall, so that humidity rapidly rose, reaching 100% at 100° F., thereafter moisture deposition on the samples occurred. A wet- and dry-bulb hygrometer T was used to indicate the humidity, and was observable through the glass window G.

TABLE III.

SPECIMENS OF MAGNESIUM ALLOY SHEET, ENAMELLED WITH NO CHROMATE TREATMENT, SUBMITTED TO HUMIDITY TEST.

Period of Test.	Composition of Finish.		
	No. 1.	No. 2.	No. 3.
	Two coats of battleship grey cellulose enamel.	One coat of stoved battleship grey enamel (Glyptal synthetic).	(*a*) Stoved red oxide primer, synthetic. (*b*) Stoved grey surfacer (*c*) Two coats of grey cellulose enamel.
8 weeks	Finish generally covered with minute blisters.	Finish generally covered with small blisters, giving a very rough appearance.	Two edges only covered with small blisters.
12 weeks	Blisters increased in size considerably.	Very little marked change.	Blisters increased in size considerably, averaging ¼ in. diameter, and some blisters on surfaces near edges.

(*b*) *Moderately Accelerated Conditions.*—Specimens were suspended side by side from a bracket on a wall facing S.W. in open weather.

(*c*) *Rigorous Conditions.*—A salt-spray test was used. The test panels were arranged obliquely positioned on glass shelves in a cabinet, and exposed to the fog of 20% salt solution atomised with compressed air. An intermittent type of sparry was used, operated during the eight-hour working day, the specimens being left in the spray-laden atmosphere overnight. They were then washed in cold running water and dried with a towel. Fig. 2 depicts the equipment diagrammatically. C is the gravity-feed salt solution reservoir, while compressed air is cleaned by passing through broken glass wetted with water A, and glass wool B. D is the atomiser. Specimens are exposed at E, F.

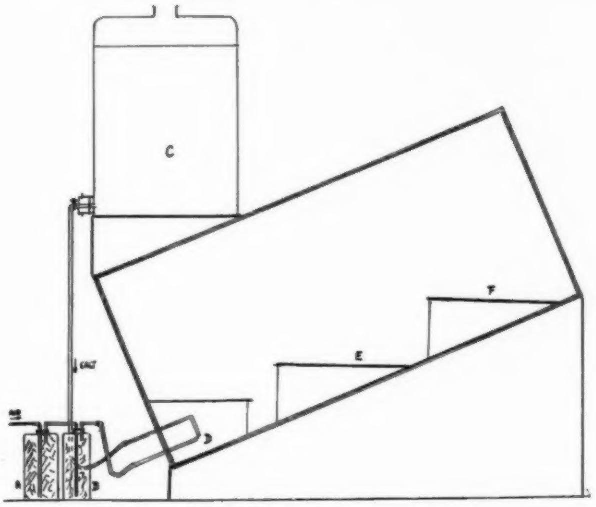


Fig. 2.—Salt-spray equipment.

The results of the exposure tests have been concisely summarised for reference in Tables III to XII, so that only brief discussion of them is needed. The tables will be considered in sequence.

Table III.—The finishes were on unchromated metal and may be considered all to have virtually failed, behaving very poorly under the relatively mild exposure conditions. Cellulose coatings are among the best for moisture impermeability, and two spray applications should ensure complete continuity with freedom from porosity. However, the moisture penetrating finish No. 1 was sufficient to attack the magnesium and consequently ruin the coating. Finish No. 2 comprises a full spray coat of glyptal synthetic stoving enamel, a variety normally providing good service on aluminium and steel in one-coat applications. It apparently permitted rapid initial permeation,

TABLE IV.

Specimens of Magnesium Alloy Sheet, Enamelled with NO Chromate Treatment Submitted to Outside Atmospheric Exposure

Period of Test.	Composition of Finish.		
	No. 4.	No. 5.	No. 6.
	One coat of stoved black enamel (oil base).	(*a*) Stoved red oxide primer, synthetic. (*b*) Stoved grey surfacer. (*c*) Two coats semi-bright black cellulose.	(*a*) Stoved red oxide primer synthetic. (*b*) Stoved grey surfacer. (*c*) One coat grey stoved enamel, synthetic.
4 weeks	Several small blisters evident.	Practically unaffected.	Unaffected.
8 weeks	Very little further change.	One edge covered with large blisters.	Unaffected.
12 weeks	Slight additional blistering.	Very little extension of the deterioration.	Minute blisters forming generally over all surfaces.

sufficient to spoil the effectiveness of the film. Finish No. 3 comprised a good stoved synthetic ground, for the final cellulose. The results seem to indicate that imperfections in the finish itself resulted in failure, these imperfections being associated with the difficulties in building a uniform coating around sharp edges of sheet, and perhaps local surface defects in the metal.

Table IV.—Again unchromated material was involved, and the finishes failed fully to withstand the conditions imposed. In finish No. 4, a single full coat applied by spray of an orthodox black oil stoving enamel, a few defects in the single coat were quickly revealed, but otherwise the finish behaved well. The shortcomings of the synthetic ground finish and cellulose top coats, finish No. 5, were again evident only by edge effect. The full

TABLE V.

Magnesium Alloy Castings, Enamelled with NO Chromate Treatment Submitted to Salt Spray Test.

Period of Test.	Composition of Finish.	
	No. 7.	No. 8.
	(*a*) Two coats stoved black undercoat (oil base). (*b*) One coat stoved grey enamel (synthetic).	(*a*) Stoved chromate primer (synthetic). (*b*) Stoved grey surfacer (synthetic). (*c*) One coat stoved grey enamel (synthetic).
1 day	Unaffected	Unaffected.
2 days	Very slight attack at edges........	"
3 "	Finish peeling off badly at all corners. (Test discontinued).	"
8 "	....	"
9 "	....	Slight attack at one corner.
12 "	....	The attacked corner further deteriorated.
26 "	....	All edges beginning to show signs of attack.
35 "	....	Deterioration of edges more marked, but condition of general surfaces still good.

TABLE VI.

Magnesium Alloy Castings, Enamelled as Received with Chromate Treatment from Supplier, Submitted to Humidity Test.

Period of Test.	Composition of Finish.		
	No. 9.	No. 10.	No. 11.
	One coat of mat black stoved enamel (oil base).	(*a*) Stoved red oxide primer (synthetic). (*b*) Stoved grey surfacer (synthetic). (*c*) Two coats semi-mat black (cellulose enamel).	(*a*) Stoved red oxide primer (synthetic). (*b*) Stoved grey surfacer (synthetic). (*c*) One coat grey stoving enamel.
4 weeks	Several white corrosion spots evident.	Unaffected...........	Unaffected.
8 "	Slight further development of corrosion.	"	"
12 "	Marked increase in extent of spotting.	"	"
24 "	Condition generally poor, casting completely covered with white spots, corrosion very bad in places.	Slight attack at two corners, condition otherwise good.	Very slight attack at one corner, but condition otherwise very good.

synthetic built-up finish, No. 6, failed badly, however, although it withstood a long period without any blemish developing.

Table V.—This is of especial interest because the specimens were complex castings, unchromated, and both had three stoved coats. The marked superiority of finish No. 8 over No. 7 indicates the beneficial effect of zinc chromate as pigment in the priming.

Table VI.—Chromated castings are involved, and the utility of the chromate treatment stands out markedly when comparison is made with Table III. The ineffectiveness of a one-coat finish (finish No. 9) is still apparent when comparison is made with finishes Nos. 10 and 11.

Table VII.—The specimens were somewhat similar to those covered by Table VI, but the test more rigorous. The one-coat finish, No. 12 proved worst, with the two-coat cellulose, No. 13, little better. On the other hand, finish No. 14 with a synthetic basis and cellulose finishing coats stood up very well indeed.

Table VIII.—This employed castings with the same finish on all specimens to obtain a rapid direct comparison between no-chromate treatment, and the rapid and slow processes. The benefits of the latter are established definitely, with slight advantage in favour of the former, under the conditions obtaining.

TABLE VII.

Magnesium Alloy Castings, Enamelled as Received with Chromate Treatment from Supplier, Submitted to Salt Spray Test.

Period of Test.	Composition of Finish.		
	No. 12.	No. 13.	No. 14.
	One coat of grey stoving enamel (blyptal synthetic).	Two coats battleship grey cellulose enamel.	(*a*) Stoved red oxide primer (synthetic). (*b*) Stoved grey surfacer (synthetic). (*c*) Two coats grey cellulose enamel.
1 day	Surface generally attacked in some places.	Very slight attack at some edges.	Unaffected.
2 days	Surface very heavily corroded in some places (test discontinued).	Attack a little further developed.	,,
7 ,,	....	General surfaces still good, but edges and corners badly corroded.	First evidence of attack by slight corrosion along one edge.
21 ,,	....	General corrosion fairly severe (test discontinued.	Attack at edge a little further developed.
35 ,,	....	....	General surfaces still unaffected, but attack at all edges.

TABLE VIII.

A Comparison of Unchromated, Rapid, and Slow Chromate-treated Magnesium Alloy Castings, Finished with Two Coats of Battleship Grey Cellulose Enamel. Results of Salt Spray Tests.

Period of Test.	Type of Chromate Treatment.		
	No. 15.	No. 16.	No. 17.
	None.	Rapid.	Slow.
1 day	Slight attack along some of the edges.	Unaffected	Unaffected.
3 days	Heavy attack at corners and along all edges, and blisters on general surfaces. Test discontinued.	Very slight corrosion at corners and edges.	Very slight attack at corners and edges.
10 days	....	Attack intensified, but still mainly confined to corners.	Intensity of attack, increased, but mainly at edges and corners.
14 ,,	....	General surfaces still fairly good, but corrosion very severe at corners and edges.	Very severe corrosion at edges and corners. Surfaces showing considerable deterioration. A little worse than the "Rapid" sample.

TABLE IX.

A Comparison of Unchromated, Rapid, and Slow Chromate-treated Magnesium Alloy Castings, Finished with Two Coats of Black Rubber Stoved Undercoating Enamel, and One Coat of Stoved Mat Black Finishing Enamel.

Results of Salt Spray Tests.

Period of Test.	Type of Chromate Treatment.		
	No. 18.	No. 19.	No. 20.
	None.	Rapid.	Slow.
2 days	Unaffected	Unaffected	Unaffected.
3 ,,	Corners and edges slightly attacked.	Corners and edges slightly attacked.	Corners and edges slightly attacked.
5 ,,	Attack at corners and edges very severe, flat surfaces fairly good.	Corners and edges heavily attacked, more general than No. 18, but less heavy.	Increased attack and some lifting of enamel, but superior to Nos. 18 and 19.
7 ,,	Enamel lifting off	—	—
10 ,,	Condition generally very poor. Test discontinued.	Very severely attacked generally, but superior to No. 18. Test discontinued.	Lifting of enamel extended.
18 ,,	—	—	Edges and corners very poor, flat surfaces fairly good. Test discontinued.

TABLE X.

A Comparison of Unchromated, Rapid and Slow Chromate-treated Magnesium Alloy Castings, Finished with Two Coats of Battleship Grey Cellulose Enamel.

Results of Outside Atmospheric Exposure Tests.

Period of Test.	Type of Chromate Treatment.		
	No. 21.	No. 22.	No. 23.
	None.	Rapid.	Slow.
26 days	Slight attack along one edge.	Unaffected	Unaffected.
60 ,,	Little further change...	Very slight attack along one edge.	,,

TABLE XI.

A Comparison of Unchromated, Rapid, and Slow Chromate-treated Magnesium Alloy Castings, Finished with Two Coats of Black Rubber Stoved Undercoating Enamel, and One Coat of Stoved Mat Black Finishing Enamel.

Results of Outside Atmospheric Exposure Tests.

Period of Test.	Type of Chromate Treatment.		
	No. 24.	No. 25.	No. 26.
	None.	Rapid.	Slow.
26 days	Unaffected	Unaffected	Unaffected.
60 ,,	Very slight attack along some edges.	,, ...	,,

TABLE XIII.

CHARACTERISTICS OF THE FINISHING MEDIA EMPLOYED.

	Battleship Grey Cellulose Enamel.	Semi-Bright Black Cellulose Enamel.	Synthetic Grey Stoving Finishing Enamel.	Synthetic Grey Stoving Surfacer.	Synthetic Red Oxide Stoving Primer.	Synthetic Zinc Chromate Stoving Primer.	First Coating Black Rubber Stoving Enamel.	Mat Black Stoving Finishing Enamel.
Compositional, %								
Volatile spirit, loss on heating, 3 hours at 110° C.	62·5	78·7	57·3	29·3	35·6	53·7	53·5	63·2
Total solids	37·5	21·3	42·7	70·7	64·4	46·3	46·5	36·8
	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Physical—								
Specific gravity at 25° C.	1·100	0·905	1·110	1·638	1·518	1·121	0·903	0·899
Viscosity centipoises at 25° C.	953	681	453	403	478	223	747	1045
Storing Conditions—								
Time, hours	—	—	½	1	½	½	2	2
Tempergture, ° F.	—	—	250	200/220	250	250	300	300

Table IX.—Similar to Table VIII, but three coats of orthodox black stoving enamel comprised the finish. The results led to similar conclusions, except that a slight advantage existed with the slower of the two chromate treatments.

Tables X and XI.—These compare with Tables VIII and IX, respectively, except that the less rigorous outside atmospheric form of test was used. Conclusions are similar.

Table XII.—The tests here were designed essentially to establish the superiority of a zinc primer over an oxide primer. It is considered that the investigation was successful, proving the point for castings without preliminary chromate treatment as well as for the chromated material. The table is self explanatory.

For the information of those directly interested, in Table XIII are summarised data concerning the various finishing media employed in the tests.

The conclusions to be drawn from these results are that special attention is demanded in the design of finishes for magnesium alloys, and that those organic finishes normally employed for miscellaneous metal components passing through the finishing department cannot be indiscriminately employed with complete satisfaction. The inclusion of

TABLE XII.

A COMPARISON OF ZINC CHROMATE AND RED OXIDE PRIMERS. MAGNESIUM ALLOY CASTINGS, UNCHROMATED OR CHROMATED BY THE SLOW PROCESS, GIVEN STOVED SYNTHETIC (GLYPTAL) FINISHES COMPRISING ONE COAT PRIMER, TWO COATS SURFACER, ONE COAT GREY FINISHING ENAMEL.

RESULT OF SALT SPRAY TESTS.

Period of Test.	No. 27	No. 28.	No. 29.	No. 30.
	Unchromated.	Unchromated.	Chromated.	Chromated.
	Chromate Primer.	Oxide Primer.	Chromate Primer.	Oxide Primer.
3 days	Very slight attack	Very slight attack	Unaffected	Unaffected.
6 „	Slight increase in attack.	Intensity and extent of attack increased.	„	Slight attack at one point.
10 „	No change	Very heavily attacked in one place and fairly heavily in several areas.	Very slight attack at one spot.	Badly attacked at one point, and lightly in several other places.
13 „	Little further change. Superior to Nos. 28 and 30.	Attack much more severe. Definitely worse than Nos. 27, 29, and 30.	Little change, far superior to Nos. 27, 28 and 30.	Little further change, inferior to Nos. 27 and 29. Superior to 28
18 „	Slight increase in attack. Still superior to Nos. 28 and 30.	Further increased deterioration.	No further change.	Slight increase in attack.
Order of Merit.	No. 2 Second best.	No. 4 Worst.	No. 1 Best.	No. 3 —

both an aqueous chromate treatment and a zinc chromate type of priming is highly desirable. At the same time, providing one of these two is incorporated in the scheme, a durable finish can result, suitable for many purposes. But the two together seem to be inevitable for securing the best results. When stoving ovens are available, and this is the case in all modern plants, baked synthetic media provide the finest coatings, and the recommended procedure can be summarised as under :—

Operation No. 1.—Clean. Use trichlorethylene plant to remove heavy-oil contamination, and then mild alkali for soap greases, etc. Use nitirc acid to remove corrosion products.

Operation No. 2.—Aqueous chromate treatment. Use rapid process unless dimensional restrictions demand slow process.

Operation No. 3.—Spray zinc chromate synthetic primer and bake.

Operation No. 4.—For castings, spray one or more thin coats of synthetic surfacer, and bake.

Operation No. 5.—Rub down lightly if essential.

Operation No. 6.—For castings, spray a full coat of synthetic finishing enamel and bake. For machined components on which operations Nos. 4 and 5 are omitted, spray two thin coats of synthetic finishing enamel and bake.

Where stoving capacity is limited for operation, No. 6 can be substituted two spray coats of cellulose-finishing enamel. Where it is absent, air drying media, preferably synthetic, must be substituted throughout. If, in this case, cellulose products are desirable from the speed point of view, it is urged that the air drying synthetic chromate primer is retained, and that a thin coat of highly pigmented paste sealer or filler be applied between it and the cellulose finishing coats.

Developments in the Physical Chemistry of Steelmaking

THE importance of recent developments in the physical chemistry of steelmaking was stressed by Mr. T. G. Bamford recently in his presidential address before the Staffordshire Iron and Steel Institute. Discussing the subject of phosphorus in steel he pointed out that in 1929 a leading British railway engineer stated that although the phosphorus content in basic open-hearth steel had been reduced to 0·04% they were no better off from the standpoint of wearing qualities than they were ten years before. It had been concluded that a high excess of phosphorus was undesirable for many applications and quite illogically that very low phosphorus must confer desirable qualities on steel. In recent years, however, as a result of work by such workers as McIntosh and Cockerell, it had been shown that phosphorus was a benefit to steel in many respects, and K. Daeves had shown that there were positive advantages accruing directly from the presence of relatively high phosphorus in steel. For instance, with 0·08% the tendency of tin plates to stick together was prevented. During the period from 1888 to 1923, there had been a consistent tendency in all countries to reduce the phosphorus in railway steels and this was eventually brought down to an average of 0·05%. At the present time Bessemer rail steels are used on the State railways of Russia containing 0·10% of phosphorus and Kirknell had stated that no flaws had been detected in rail steels containing 0·12% of phosphorus, which had been in service for ten years.

Oxygen in Steel

Turning to the subject of oxygen in steel, Mr. Bamford stated that it had been shown that oxygen could never be completely removed from the deadest of dead-killed steel. By applying certain well-known laws of physical chemistry and using one particular property known as the free or available energy of each substance, it had been shown that cadmium and magnesium would form much more powerful deoxidisers than aluminium. Manganese and chromium had a certain small deoxidising influence, but in this respect were much less potent than silicon. Zirconium was almost equivalent to aluminium as a deoxidiser while vanadium and titanium lay between aluminium and silicon in that respect.

In July last, Weidtmann published the result of work on differently killed free-cutting steels, and he showed that in both turning and drilling tests the tools wore best with manganese-killed steel, and that chromium came second with silicon, zirconium and aluminium following each other in the series. The best deoxidiser therefore, showed up as most detrimental in its influence on the free-cutting qualities. On the other hand, unkilled free-cutting steels are red-short on working. Oxygen content of steels appears to have other vital influences on the properties of the metal, and in fact, to influence its behaviour during working, under heat-treatment and in service. This fact has been recognised in Germany for many years, it is absorbing the close attention of American steelmakers, and our own manufacturers are by no means lacking in the thought which is being given to it.

Coarse and Fine Grain

Referring to grain size, Mr. Bamford mentioned that it was quite generally held that sub-microscopic refractory particles, mainly oxides, were the cause of fine grain. Steels of fine grain were shallower hardening and carburised less deeply than coarse grain, but even for carburising steels, fine grain may have decided compensating advantages. Fine-grained steels had a much wider heat-treating range because the austenite which was produced did not coarsen as was the case when a coarse-grained steel was heated. Fine-grained steels were less embrittled by cold work, and this property was of advantage in punching heavy sections, in heavy reductions by cold rolling, and they had higher impact resistances at low temperatures. Given ordinarily good furnace practice, positive production of coarse- or fine-grained carbon steel at will could be obtained by controlled-ladle addition of aluminium and a controlled-reactive

oxygen content, which in turn depended largely upon the carbon, manganese and silicon content of the steel. It might also appear that other elements such as titanium and zirconium might substitute or be used in conjunction with aluminium. Naturally the amount of aluminium and silicon required to give fine grain resulted in a fully-killed, deeply-piping steel.

Ageing of Steel

Discussing the ageing of steel, Mr. Bamford pointed out that there is considerable evidence for believing that this property or gradual change in properties which take place after quenching and after cold deformation is influenced to a considerable extent by the oxygen content of the steel. In all respects the most complicated and in some ways the most interesting example of ageing is that of "strain ageing," the basic cause of which seems also to be responsible for "blue brittleness," and also for the extraordinary hardness which develops in steel while being rolled or drawn in the temperature range around 200° C. The remedy is simple. Any sort of cold deformation, even slight, which positively causes a small but definite slip in each grain takes them through the stage of weakness and removes the tendency to sudden local yield. This is accomplished by a stretcher levelling, a pinch pass, or roller levelling. At this point, however, the element of ageing enters. Steels known as non-ageing steels are being manufactured by a practice which is primarily expected to reduce the concentration of dissolved oxygen to a minimum. While such steels are not entirely free from strain ageing and are prone to stretcher strain, the rate of change in them from the cold-worked state is almost negligible. It seems justifiable to regard oxygen almost certainly as responsible for at least strain ageing.

Ultra Sound Waves

A recent innovation in experimental physics is just beginning to find application which may prove of great value to the industry in future. This refers to ultra-sound waves, whose character resemble ordinary sound waves, except that they are of higher frequency, and like light can be focussed in certain directions, and will give shadow zones, when suitable objects are placed in their path. The permeability of iron and steel for them is very great. If cracks, pipes or blowholes were present in the metal its transmitting power became extraordinarily small and its absorptive power for the sound waves very great, making a proofing test of steel readily possible. They can also be used to raise the tensile strength of steel, to accelerate the nitriding process, to hasten the process of solidification of cast metal and to modify its structure, also to promote the alloying of two metals. It has also been shown that they can be used to de-gasify molten metal. Dust particles in flue gases will precipitate and agglomerate together quickly and completely under their influence.

Finally, reference was made to the work which had been done on the ultimate strength of metals. A rough mathematical estimate of the ultimate strength of a single crystal gave values about one thousand times as great as those measured experimentally. A full understanding of the reason for the great difference in the values had not come yet. When it came, as it would it was bound to bring with it new possibilities for the use of metals in the service of mankind.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS

Nov. 6. Thomas Hawksley Lecture: "The Spectroscope and the Atom," by Professor Alfred Fowler, C.B.E., D.Sc., F.R.S.

EDUCATIONAL GROUP.

Oct. 30. "Some Aspects of American Technical Education." Introduced by C. H. Spiers, Ph.D., M.A., B.Sc.

IRON AND STEEL INSTITUTE

Oct. 29-30. Autumn Meeting.
Additional sessions held in the Lecture Theatre of the Institution of Civil Engineers.

INSTITUTE OF METALS

BIRMINGHAM SECTION

Nov. 5. "Present Trend in Alloy Constructional Steels," by J. A. Jones, M.Sc.

LONDON SECTION

Nov. 12. "Research in the Iron and Steel Industry," by W. H. Hatfield, D.Met., F.R.S.

NORTH-EAST COAST SECTION

Nov. 10. "Spectographic Analysis of Metals," by M. Milbourn, A.R.C.S., B.Sc.

SCOTTISH SECTION

Nov. 9. The Nickel Industry—Some Recollections, by W. R. Barclay, O.B.E.

SHEFFIELD SECTION

Nov. 13. "Lead Mining in Derbyshire," by L. B. Williams, B.A., B.E.

SWANSEA SECTION

Nov. 10. "Gases and Metals," by C. J. Smithells, M.C., D.Sc.

MANCHESTER METALLURGICAL SOCIETY

Nov. 4. Joint meeting with Institute of Metals.

INSTITUTE OF BRITISH FOUNDRYMEN

BIRMINGHAM BRANCH

Nov. 6. Presentation of Reports of Sub-Committees of the Technical Committee.

EAST MIDLANDS BRANCH

Oct. 31. Joint meeting with Sheffield Branch at Derby. Visit to Works of International Combustion, Ltd. "The Grinding Wheel in the Foundry," by S. L. Ireland.

LINCOLNSHIRE SECTION

Oct. 31. Presidential Address.
"Mechanical Aids for Increased Foundry Production," by J. Timbrell.

LANCASHIRE BRANCH

Nov. 7. "Foundry Refractories," by W. J. Rees, M.Sc.

BURNLEY SECTION

Nov. 10. "Making a Cone-Drum in Green Sand," by G. Dewhurst.
"The Melting and Casting of Non-Ferrous Metals," by R. Hargreaves.

LONDON BRANCH

Oct. 23-24. Joint Meetings with the Birmingham Branch.

Nov. 4. "The Production of Dense Iron Castings," by J. H. Williams.

EAST ANGLIAN SECTION

Nov. 5. "Some Visits to Foundries in U.S.A.," by T. Makemson.

MIDDLESBOROUGH BRANCH

Oct. 23. "Cupola Refractories," by W. J. Rees, M.Sc.

NEWCASTLE BRANCH

Oct. 24. "Science in Relation to the Foundry," by E. C. Pigott.

SCOTTISH BRANCH

Nov. 14. "Mould and Core Washes at Atmospheric and Elevated Temperatures," by R. F. Hudson.

FALKIRK SECTION

Nov. 2. "Recent Developments in Cast Iron," by H. Cowan, B.Sc.

SHEFFIELD BRANCH

Oct. 31. Joint Meeting with East Midland Branch at Derby.

Nov. 5. Short Paper Competition.

WALES AND MONMOUTH BRANCH

Oct. 24. "Melting Metals in the Foundry," by S. E. Dawson.

(*Continued in previous column.*)

(*Continued from next column.*)

Nov. 14. "Some Technical Observations on the Production of Cast Iron," by J. H. Williams.

WEST RIDING BRANCH

Nov. 14. "Dimension Tolerances for Castings with particular Reference to Malleable Cast Iron, by F. K. Neath, B.Sc.

INSTITUTE OF MARINE ENGINEERS

Nov. 10. "Air and Gas Compressors," by James Hendry.

THE ROYAL AERONAUTICAL SOCIETY

Nov. 12. "The Part Played by Skin Friction in Aeronautics," by Dr. F. W. Lanchester, F.R.S.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

The United Kingdom and International Trade

WORLD trade conditions become more and more interesting. The devaluation policy embarked upon by France and other Continental countries, including Italy, is resulting in an adjustment of currencies which is expected to have favourable repercussions on the trend of international trade. Much, however, will depend upon the nature of the developments, but it is hoped that they will be in the right direction, and that they will be assisted by the sytem of close co-operation adopted by this country and the United States. This devaluation may be regarded as a move towards the stabilisation problem, because any scheme which has for its object the promotion of world recovery in trade must provide for an adjustment of anomalous currency relationships, amongst which the over-valuation of the gold bloc currencies predominated. Further progress in this direction is, unfortunately, being delayed by the fixing of a consistent sterling rate of the dollar between American and British authorities. But the foundation must be laid for the restoration of economic confidence, that is, the creation of conditions favourable to the more dispassionate movement of funds, which alone can bring full international recovery, conditions which can only be created through political pacification.

Remove Trade Barriers

From time to time we have stressed the need for some concerted plan to remove trade barriers in the interests of international trade, it is therefore, interesting to note that the removal of trade barriers has been urged at Geneva by the Financial Secretary to the British Treasury. After welcoming the devaluation of the gold bloc currencies and the Three Power Monetary Agreement, he called upon nations to join in a movement for the restoration of world trade. The effort of devaluation, in harmonising domestic prices with world prices, acted in themselves as a sort of automatic addition to import duties so that quantitative restrictions of imports lost the reason for their application. Continuing his remarks, he considered the present situation presented a signal opportunity for clearing away obstacles to international trade, at the same time he warned the Committee that the British Government would be faced with the strongest pressure from British interests to take measures to counteract the intensified competition resulting from foreign devaluation, but once a move has been made by other countries the way may be clear for a more widespread lowering of tariff barriers.

Effect of Devaluations

It is probably necessary to sound a note of warning against undue optimism regarding the immediate effect of these devaluations of currency and a careful watch is no doubt necessary to ensure that British interests in the home market, and competitive markets overseas are not prejudiced, but it is difficult to understand why our foreign competitors are expected to make the first move towards a lowering of tariff barriers. The strongest pressure would be exerted by the many interests concerned to prevent such a reduction unless it can be shown to be a profitable venture. The fact is that tariffs create very strong interests in every country that promotes them, and it becomes increasingly difficult to return to a freer international trade. Until governments agree among themselves to discuss the removal of trade barriers in a calm and rational manner, it is advisable to view the international situation without undue optimism, when it will be seen that all possible steps should be taken to promote still further domestic business expansion.

The Home Trade and Industry

It is gratifying that the improvement in the home trade shows no signs of abating, especially as improved activity has extended to practically all branches of British industry. There is marked activity in the capital equipment industries, shipbuilding, building and public works contracting, road and air transport. Demands for various grades of steel, for instance, are greater than ever. In some grades a shortage exists and the position is becoming so acute that negotiations are in progress with a view to a further increase in the import quota of semi-finished steel from Continental producers. The scarcity is not confined to one grade of steel; consumers of structural steel are finding difficulty in obtaining full supplies, but it is thought that an increase in the import of semi-finished steel will relieve manufacturers and enable them to increase, to some extent, the output of structural steel. Steel plants producing joists, sections and plates are in many instances working to capacity, and the possibility of increasing the supply of structural materials is limited. But the demand for all classes of steel is unprecedented. The rate of production during the first half of the year was at an average rate of nearly a million tons a month—a figure which not only exceeds the 1935 level, but also that of 1929. The new plant at the Cardiff works of Guest, Keen, Baldwins Iron and Steel Co., Ltd., described in this issue, is making a substantial contribution in meeting the need for more steel.

Production in the iron and steel trade is such that there is a marked stringency of raw materials. The supply of pig iron is not satisfactory. Steelmakers have modernised their plants and increased their capacity and, with increased demands for steel, steel scrap has been used in greater quantities than formerly, but recently supplies have fallen off and the demand for pig iron has increased, and supplies are not available to meet urgent needs. The acute shortage is likely to continue unless idle blast-furnaces can be put into operation. But, in view of the political disturbance in Spain, there is a definite iron-ore problem, and ore is being imported from other quarters. The demand for foundry pig-iron continues to be acute, and Messrs. G. and R. Thomas Ltd., Bloxwich, near Walsall, recently lighted their No. 1 blast-furnace and are now producing all-mine cylinder and cold-blast pig-iron, as well as a low phosphorus quality.

Particular mention is made of the unprecedented demand for iron and steel because it is a basic industry, and as such, gives an indication of the activity of those industries which depend upon a ready supply of comparatively cheap structural materials, but it should be appreciated that the non-ferrous industry is also enjoying great activity. In the aluminium industry, for instance, metallurgical progress has given the alloys of this metal a wide application, particularly in the transportation field, and present activities are far in excess of the most optimistic expectations of a few years ago. Actually there is marked activity in nearly all the principal industries of the United Kingdom.

Although there is cause for gratification in the home trade, the fortunes of many industries are associated with overseas trade as a whole, and the Government should continue to take all possible steps to bring about a reasonable increase in world trade.

Some members of the National Association of Hæmatite Pig Iron Manufacturers on a recent visit to the Ford Works, Dagenham.

New A.S.T.M. Specifications for Aluminium Base Alloys

At a recent meeting at A.S.T.M. Headquarters, the Society's Committee E-10 on Standards took action involving a number of items pertaining to non-ferrous metals. On the recommendation of Committee B-7 on Light Metals and Alloys, new specifications for aluminium-base alloy permanent mould castings were approved. The A.S.T.M. designation B 108—36 T, has been assigned to this new tentative standard. The specifications cover practically the entire aluminium-alloy permanent mould field, and the committee in submitting the specifications indicated that they were representative of the present practice in the field. While the production of the type of castings covered has for some time exceeded many million dollars' worth each year, there has been no A.S.T.M. specification developed.

The requirements cover castings having a specific gravity of three or less. Eleven types of alloys designated 1 to 11 are specified. Two classes of castings are referred to, namely, standard commercial quality and Class A alloys, where the greatest freedom from impurities is required. In addition to chemical composition and physical properties required, the specifications also list precision requirements for methods of chemical analysis which are expressed in per cent. of specified value. The range of minimum tensile strength requirements is from 21,000 lb. per sq. in. for two of the alloys in the as-cast condition to 42,000 lb. per sq. in. for certain of the alloys as heat treated.

The committee has also included a table of supplementary data, indicated as being approximate, in which the principal uses of the various alloys are given, information on approximate specific gravity, and whether the machinability, corrosion resistance and casting properties may be considered poor, good, fair or excellent, and whether the alloys are responsive to heat treatment.

Extensive revisions were approved also on the recommendation of Committee B- involving the existing specifications for Aluminium-Base Alloy Sand Castings (B 26). The changes provide the elimination of certain alloys which have become obsolete and the addition of several new alloys now in commercial production for which there has been a demand for specification requirements. Certain of the other alloys have been revised in order to bring them in line with current practice. Whereas the former specifications provided for nine alloys, the new specifications cover twelve. Tables of chemical composition and physical properties specified are provided and also requirements for methods of chemical analysis. In a series of explanatory notes the committee has incorporated information about each alloy covering specific gravity, pattern shrinkage, machining qualities and special features.

Movable Nickel Smelting Plant for the Urals

The construction of a nickel-smelting plant, which can be moved from place to place, is now being completed at the Rezh nickel deposits, about 56 miles from Sverdlovsk. This is said to be the first plant of its kind in the world. According to Mr. Byezhitz, chief engineer of the Soviet Nickel and Tin Industry, there is much nickel in the Urals, but the nickel ore is scattered in numerous places with comparatively small deposits in each. The smelting of nickel ore in large plants is very expensive, especially when the deposits in a particular area have been exhausted, and ore has to be transported from considerable distances. Actually the delivery of ore to the Ural plant represents 30% of the net cost of the production of nickel.

The problem has been studied in order to determine ways and means of reducing this tremendous expenditure on transport, and this has resulted in the erection of a movable nickel-smelting plant which is claimed to be the first in the history of the technique of the nickel industry. The entire plant, including the building, furnaces, machinery, electric power installation and workers' dwellings, is so constructed that it can be dismantled within a period of a month, and reassembled in another place in six months ready for nickel smelting. It is expected that the ore deposits of Rezh, where the plant is now being completed, will be exhausted in about four or five years, when it will be moved to a new nickel-deposit area.

The economic advantages of such a portable plant are claimed to be of great importance. Capital investments per ton of nickel produced will be much lower than in large plants. The Rezh nickel-smelting plant will not produce metallic nickel, but will smelt nickel stone containing 30% of nickel. This stone will then be sent to the Ufalei Nickel plant (also in the Urals) for the final extraction of the nickel. This experiment is of considerable interest, and the plant is expected to speed-up the working of the deposits of this valuable metal.

Aluminium Motor Transport Bodies

The use of aluminium alloys in motor-truck construction.

The weight of the aluminium alloy motor-truck body shown in the accompanying illustration, is just over 4 cwt., as compared with the weight of a similar size timber body of just over 8 cwt. Originally the drop sides were in wood with a central support; by the use of an aluminium alloy, however, these are now constructed in one piece.

In this construction the highly stressed members, such as the under-framing, and also special sections used for combined vertical stiffeners and hinges on the drop sides and ends, Hiduminium R.R. 56 alloy was used. All sheeting including the floor is in hard rolled R.R. 66, together with special rolled sections fitted round the top edge of all vertical sides, also along the bottom of the drop sides and end. The latter alloy was chosen because it withstands atmospheric conditions without protection. The outside is coated with aluminium paint, including the under-framing.

Progress in Iron and Steel Production

The New Iron and Steel Plant of Messrs. Guest Keen Baldwins Iron and Steel Co., Ltd., at East Moors, Cardiff.

Development in the economical production of iron and steel has made rapid strides in recent years, particularly in this country where many reorganisation and reconstruction schemes have been executed, and which has been responsible for the substantial rise in production figures. The most recent of the reconstruction schemes to be completed is that at the East Moors Works at Cardiff, which can be claimed to have the most modern plant and layout for the production of pig iron billets, sheet bars and small sections of various kinds. The plant is described in this article.

THE East Moors Works at Cardiff were originally built in 1889–1893 by the Dowlais Iron Co., Ltd., and consisted of blast furnaces, open-hearth shop, and a plate mill. On the amalgamation of Guest Keen and Nettlefolds, Ltd., and Baldwins, Ltd., in 1930, to form the British (Guest Keen Baldwins) Iron and Steel Co., Ltd., the works at Port Talbot, Cardiff and Dowlais were formed into one concern. For economical reasons steel manufacture was concentrated at the Port Talbot and Margam Works, which were able to supply the Company's trade in rails, plates and sections, and in 1931 steelmaking at Cardiff ceased, but the blast-furnace plant was kept working.

Photo by Britton and Cox, Ltd., Cardiff.

General view of blast furnaces.

Photo by Britton and Cox, Ltd., Cardiff.

Tapping one of the blast furnaces.

The site at Cardiff is peculiarly suitable for a steel works producing billets and sheet bars and, in view of improved conditions for the iron and steel industry, Guest Keen Baldwins decided, in 1934, to erect a complete iron and steel plant on it with a capacity of 500,000 tons of pig iron and 350,000 tons of steel. The International Construction Co., Ltd., were engaged as consulting engineers, Sir Robert McAlpine and Sons were engaged to carry out all excavations and foundations, and plans were drawn up to get the new works into production early in 1936.

Of the old plant there remain only the blast furnace and sinter plants with blower house and repair shops. The new works consist of a coal washery and coke-oven plant, an ore-handling plant, the rebuilding of two of the three blast furnaces and other reconstruction of the blast-furnace plant, a new gas-cleaning plant with gasholders, open-hearth plant, rolling mills and all accessory plant. The programme of reconstruction was strictly adhered to, and coke was made on January 1 this year, steel being made and rolled the following day, and in the second week in February production had reached 4,000 tons per week.

The products of the plant consist of by-products from the coke-oven plant, pig iron (basic and hæmatite), billets, sheet bars, and small sections of various kinds. Outstanding features of the plant are its simple and clean layout and the absence of smoke—all heating being obtained by means of blast-furnace and coke-oven gas. All buildings are well lighted, and provision has been made throughout for easy access to all roof and wall glazing for cleaning purposes.

COAL HANDLING AND WASHERY PLANT

The coal handling and washery plants, which were installed by Messrs. Simon Carves, Ltd., were designed to meet specific requirements and to handle coal at the rate of 170 tons per hour. Eight incoming coal sidings are laid out, which converge to two immediately in front of the wagon hoists and tipplers, and two shale wagon sidings converging to one at the shale weighing machine. The inclination of the sidings to and from the wagon tipplers is such that when the wagons have been marshalled on the incoming sidings no further locomotive attendance is required. In addition two electric capstans are fitted. The capacity of the sidings is approximately 2,000 tons of coal loaded in 20-ton wagons, and is more than sufficient for a full day's washing. To compensate for the difference in rail levels, two wagon hoists are situated immediately in front of the wagon tipplers. These hoists lift the wagons to the level of the tipplers and weighbridge.

Photo by Britton and Cox, Ltd., Cardiff.

Part view of the works, showing the coal-handling and washery plants in the background.

Two Pooley recording and indicating double weighbridges are installed. The weighbridge tables are situated at each end of the two coal-receiving hoppers and accommodate the tippler cradles. This enables the wagons to be weighed full, tipped, weighed empty, and run off to the empty wagon sidings. The double-ended tipplers are of the overhead winch type, the lifting cradles being placed over the weighbridge platforms. The coal is tipped into two receiving hoppers from which it is fed on to the inclined belt to the washery by means of reciprocating feeders and a collecting belt.

A 2-in. wire mesh inclined vibrating screen is installed at the delivery end of the inclined belt to washery. The oversize coal from this screen passes through a British-Jeffrey-Diamond single-roll breaker and is crushed down to convenient washing size. The total coal passes into a receiving bin built under the breaker and arranged to deliver direct into the de-dusting plant.

The de-dusting plant is the Simon-Carves patent type with enclosed air circuit. The coal falls into the de-dusting chamber on to a screen formed of triangular-shaped bars and is met by a stream of air supplied by a paddle-type fan. The amount of air blown through the coal can be varied in accordance with the size of dust to be extracted. The de-dusted coal passes from the bottom of the extraction chamber into a steel chute where it is met by a stream of water and carried into the wash-box. The dust-laden air passes out from the top of the extraction chamber into a conical cyclone where the dust is separated from the air and is carried down chutes to either of the two dust bunkers.

The washer box is the "Baum" type, designed to treat 170 tons of coal per hour. It is 17 ft. long by 14 ft. 6 in. mean width, with air chambers divided into five compartments. The box is fitted with air valves of the piston type, driven by eccentrics, and automatic rotary-type shale extractors driven by variable gear, controlled by floats at each end of the box. A "Hirst" patent stirrer is fitted in the second half of the box. The stirrer is reciprocated at fifty 2-in. strokes per minute.

Shale elevators are installed at each end of the washer box the shale being carried to the boots of the elevators by means of worm conveyers. The dirt leaving the elevators falls into a 100-ton storage bunker, from which it is loaded directly into rail wagons and weighed.

There are 16 drainage bunkers with a total capacity of 3,200 tons, each 20 ft. diameter with conically shaped bottoms. Washed coal from the washer box is flushed with water along two central troughs built longitudinally along the top of the drainage bunkers. Each drainage bunker can be isolated for separate filling. Mild-steel removable-drainage-water collecting trays are provided under each bunker, the water running into a main sump for recirculation.

Two main water pumps are installed, one being a spare. Water is delivered into a balancing tank of 5,000 gals. capacity built on top of the washery building, from which tank it is fed through the wash box and along the various troughs. The water carrying washed coal to any of the drainage bunkers first fills up the bunker then overflows through openings at the top into a trough leading into two slurry-settling tanks or "Spitz-kastens." The Spitz-kastens work in series and are 20 ft. square with conical bottoms, with a total capacity of 110,000 gls. Water overflowing from the Spitz-kastens runs into a return tank of 68,000 gals. capacity for recirculation.

A Simon-Carves patent slurry plant built underneath the Spitz-kastens consists of two sets, each with two rapidly vibrating frames 12 ft. long by 5 ft. wide, fitted with $\frac{1}{4}$ m.m. mesh-wedge wire sieves, driven through hickory connecting rods. Two fixed inclined sieves distribute the slurry uniformly over the vibrating sieves. Slurry is fed from the bottom of the Spitz-kastens through cast-iron regulation cocks. The de-watered slurry falls from the screens into a worm conveyer and paddle mixer, where it is mixed with a regulated flow of dust from the dust hoppers. The worm conveyer delivers the mixture on to an inclined belt carrying the bulk washed coal blend to swing hammer mill crushers. The effluent from the slurry screens runs into a drainage sump for recirculation, or into external storage ponds.

There are three external storage ponds built 10 ft. deep below ground level, having a total capacity of over 156,000 gals. These ponds are brought into commission at the end of each day's work to collect overflows from inside tanks and bunkers and also for "tapping out" slurry when the slurry screens are under repair. All water and slurry is pumped from the ponds back into circulation by means of an 8-in. diameter pump.

Coal received already washed is handled in the normal manner up to a point immediately before the raw coal breaker. Chutes are arranged to by-pass the de-dusting plant and washer-box and convey the coal on to a central conveyer belt. This belt in turn delivers the coal through chutes on to either of the shuttle-belt conveyers installed to travel over the top of the drainage bunkers. These belts are driven by 10-h.p. motors fitted with reversible starters, so that the coal can be fed into any bunker. The bulk of the coal blending is done on the central belt running underneath the drainage bunkers.

There are six sets of travelling-belt feeders, three arranged under each row of drainage bunkers, the belts being at right angles to a main central belt, and they can be brought into position under any drainage bunker. Each feeder is worked by a separate 5-h.p. D.C. motor, variable speed, 960/320 r.p.m. The feeders carry a regulating gate (rack-and-pinion type) fitted over the belt, and movable hoppers direct connection to the bottom of the bunkers.

Two swing-hammer mill crushers are installed of the Jeffrey-Diamond type, each capable of crushing 170 tons per hour, to give 90% through $\frac{1}{8}$-in. square mesh sieve. The crushers are flexibly coupled to 300-h.p. motors. The coal blend passes through the crushers on to a collecting belt which delivers the coal on to the first of two inclined belts delivering on to a revolving shuttle-belt conveyer fitted over the top of the ovens coal service bunker. This conveyer comprises a belt conveyer mounted on a revolving undercarriage. By means of the conveyer the two sections

of the service bunker can be filled level full and the rotary action reduces segregation to a minimum.

The total capacity of the service bunker is 2,200 tons of dry coal, and it is divided into two compartments of one-third and two-thirds, respectively. These two compartments are essential for the separation of low phosphorus and high phosphorus coal blends. A series of concrete water tanks of 75,000 gals. capacity are situated on the bunker roof for supplying water under pressure to any part of the coke ovens and by-product plant.

The starting of the various motors concerned in getting the coal from the tipplers through the washery are operated on push-button control, and are electrically connected in sequence in such a manner that they can only be started or stopped consecutively. This arrangement prevents over-running and piling up of coal with resulting blockages. The arrangement also applies to the whole of the washed and crushed coal circuit up to the service bunker.

It is worthy of note that since the commencement of the plant in December, 1935, all slurry and dust produced has been returned to the washed coal, and the water is kept comparatively clean by the particular system of draining.

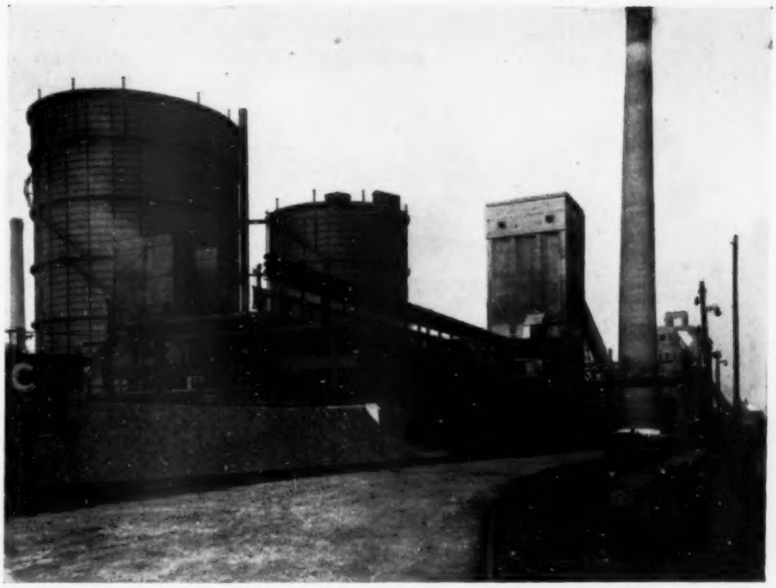


Photo by Britton and Cox, Ltd., Cardiff.

General view of the coke-oven plant, showing the blast-furnace and coke-oven gasholders.

COKE OVENS AND BY-PRODUCT PLANT

The ovens service bunker, coke ovens, coke-screening and handling plant, including the handling of purchased coke, by-product plant, and the machinery associated with those plants, were installed by The Woodall Duckham Vertical Retort and Oven Construction Co. The plant was put down for the production of approximately 6,000 tons of blast-furnace coke with 18 hours coking time per oven charge and the handling of all by-products. The ovens are the Becker patented cross regenerative combination type. They are 58 in number and are built in two batteries of 29 each. Each oven is 43 ft. ½ in. long face to face of oven brickwork giving 40 ft. 8 in. length face to face of oven doors. The mean width is 18 in. with a pushing taper of 2½ in. The height is 12 ft. 6 in.

The ovens are each fitted with four coal-charging holes nad one gas off-take at the top of the discharge end of oven. There are 120 regenerator chambers each being 40 ft. 7½ in. long inside walls and 13 ft. 5 in. from oven top to oven floor. Each chamber is divided into two compartments by a cross wall, parallel to the centre line of the battery. This, in effect, makes four regenerators for each oven. These chambers have individual connections to the reversing valves through rectangular openings at the bottom of the regenerator walls. The regenerators are filled with chequer firebrick work. The oven chambers, combustion flues and regenerator walls are all built of high-grade silica bricks laid with silica cement.

The Cardiff installation differs slightly from previous batteries of Becker ovens built in this country in so far as there are eight cross-over flues built over every other oven chamber whereas in earlier batteries there have been only six.

Between each oven is a heating wall, comprising 27 vertical flues. Combustion takes place at the bottom of these flues, and the products of combustion pass upwards through the eight cross-over flues and downwards on the opposite side of the oven through the regenerators, where heat is absorbed by the firebrick filling, and so to the chimney flue. At regular intervals the cycle is changed round, the waste product flues become combustion flues and the flues where combustion previously took place carry the products of combustion. The change-over interval may be altered to suit requirements. The entire machinery, being mechanically operated, is automatically put in motion by an Igranic timing switch. Should the reversal fail to take place at the appointed time a Klaxon horn blows a warning and if the failure is due to electrical trouble an auxiliary steam engine has been installed which can be quickly thrown into operation.

The ovens being of the compound type may be heated either by part of the high calorific value coke-oven gas produced or by blast-furnace gas. In the event of the ovens being heated by coke-oven gas all the regenerators are used for the preheating of air and the absorption of heat from the waste gases.

When the ovens are being heated by the low calorific value blast-furnace gas it is necessary, in order to obtain the requisite flame temperature, to preheat this gas as well as the air. In order to do this the blast-furnace gas main is constructed below the level of the bottom of the regenerators and the gas leaving the main passes into the bottom of one compartment of the regenerator whilst air passes through the adjoining compartment. Combustion takes place at the bottom of the vertical flues as when burning coke-oven gas. The waste products pass through the same cycle, the same number of regenerators being used for absorption of heat. Any number of ovens may be fired by blast-furnace gas and the remainder by coke-oven gas or vice-versa. The oven doors are of the Wolff self-sealing type with metal-to-metal joints and with careful cleaning after each extraction are gas-tight when refitted.

The ascension pipes which are built over the discharge end of the ovens are fitted with steam jets. When an oven is being charged, the steam jet in the ascension pipe leading from the oven is turned on and the oven is charged on the "Main." In this way very little smoke escapes to the atmosphere.

The pusher machine, charging car, door-lifting machine and coke car were constructed by the Wellman Smith-Owen Engineering Corporation. The electric locomotive for driving the coke car was supplied by Messrs. Hawthorn, Leslie of Newcastle-on-Tyne. The electrical coal charging lorry car comprises four steel hoppers mounted on a chassis which also supports an operating cab housing all the controls and levers. Mechanical agitators are fitted in each hopper to facilitate discharge of the coal into the ovens. The gross and tare weights of coal and car are taken on a weighbridge built underneath the service bunker. The

spillage crane is of the runway type and is a standard design of Messrs. William Morris. It is used as follows :—

Any coal withdrawn from the ovens on levelling down the charges falls into a hopper attached to the pusher machine. This hopper, when full, is emptied into a skip, housed below the level of the pusher machine track. The spillage crane hoists up the skip as required and raises it above the level of the coal-charging lorry car, discharging the coal into one of the hoppers of the car.

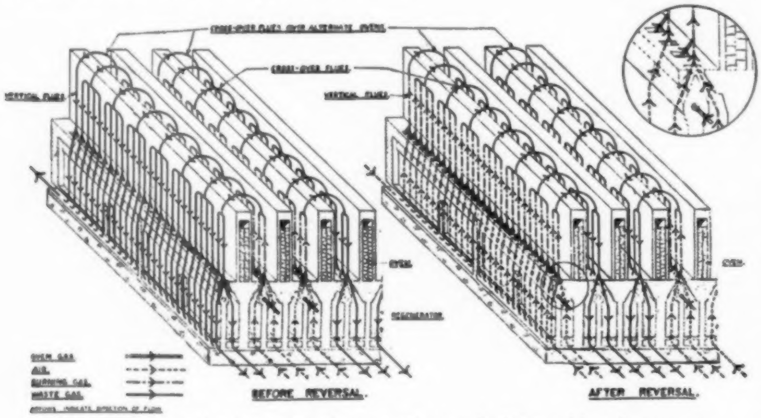


Diagram showing heating cycle of ovens when underfiring with coke-oven gas.

The coke-pusher machine is fitted with pusher rack for discharging the coke from the oven and a levelling arm for levelling the charge of coal in the oven. This arm can be raised or lowered within certain limits according to the height of charge required and also carries the pusher-side door extraction machine. The electrical system is interlocked to prevent two operations being switched on at the same time. In the event of failure of electrical supply whilst the ram rack or levelling arm is in the oven, the gear is arranged for hand operation.

The door extractor machine on the coke side consists of an extractor head carried at the front of a travelling carriage arranged to run backwards into the machine for withdrawing the door. Electrical interlocks assure that the machine cannot travel unless the extractor head is clear of the ovens. The coke guide supports the coke leaving the oven to the coke car.

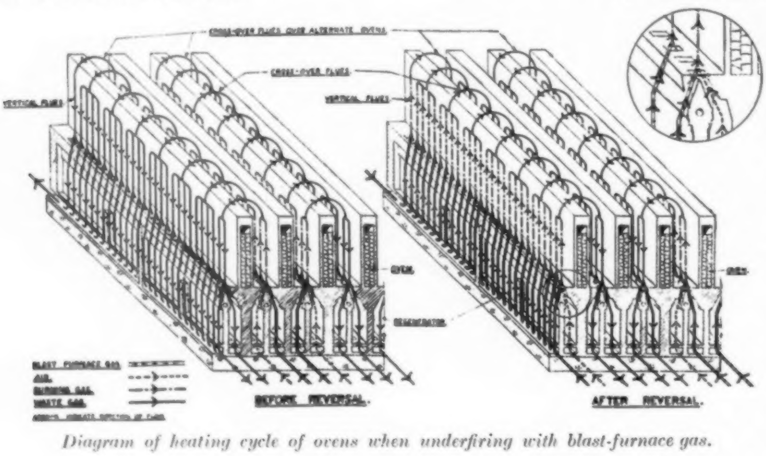


Diagram of heating cycle of ovens when underfiring with blast-furnace gas.

A coke-quenching car conveys the hot coke to the quenching station and thence to the coke wharf. It is about 40 ft. long and has a sloping bottom made up of cast-iron plates, and four discharge gates made of cast-steel, the latter being operated by compressed air supplied by one compressor on the locomotive. Provision is made for hand operation of the discharge gates in the event of failure of air supply. The quenching station is a brick tower, 56 ft. high, fitted with perforated water pipes for quenching the coke. The steam from the quench passes upwards through the tower to the atmosphere. Associated with the tower is an overhead water tank of 10,000 gals. capacity, electric automatically controlled pumps, breeze-settling sumps, etc. The water for quenching the coke is automatically turned on as the coke car enters under the tower.

The quenched coke is discharged on to a sloping coke wharf which has a total length of 125 ft. It is paved with blue brick tiles and is fitted at the bottom with discharge gates feeding the coke on to a rubber conveyer belt. This conveyer carrying the run of oven coke to the screening plant is fitted with an automatic weigher and totaliser of Blake-Dennison manufacture. In this way all coke and breeze leaving the wharf to the screening plant is weighed.

Two coke screens are provided, one to handle all the coke from the Cardiff ovens and the other to grade coke purchased from outside markets. The screens are of the double deck "Gyrex" heavy type supplied by Fraser and Chalmers, and are arranged to separate the coke into suitable size. Present sizes produced are: Over 2 in., 2 in. to 1 in., and 1 in. to nil. These sizes can be easily altered by changing the screen-mat sizes. The sized blast-furnace coke from the screens is conveyed on rubber-belt conveyers direct to the blast-furnace bunkers. The smaller sizes fall into bunkers built underneath the coke screens. The coke-screening and handling plant is designed to handle 120 tons of oven coke per hour.

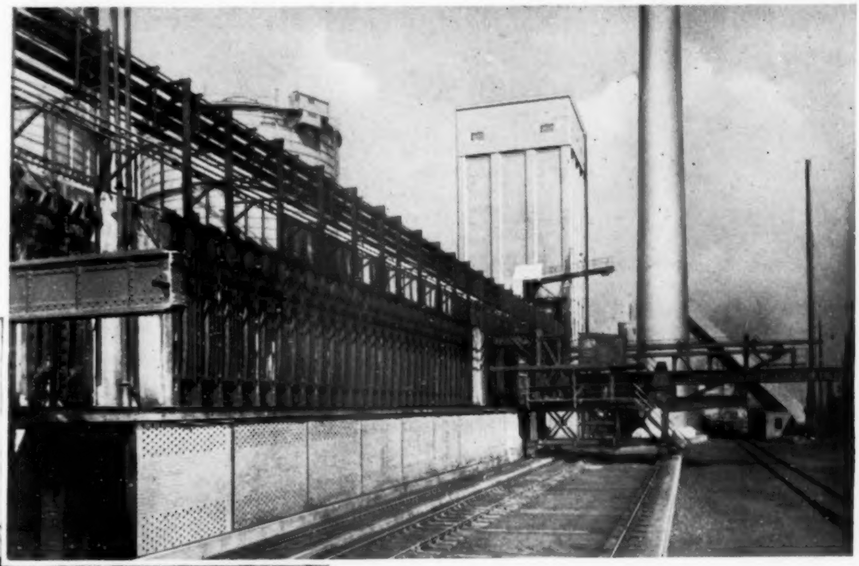
The handling plant for purchased coke consists of electrical haulage gear supplied by the Uskside Engineering Co., for hauling full wagons from the sidings into position for tipping, an Avery weighing machine, a side-discharge wagon tipper manufactured by Messrs. H. Lees, of Glasgow, a reception wharf and rubber conveyer belt from reception wharf to screening plant. The tipper is of the cradle type and accommodates the weighbridge platform so that the wagons are weighed, tipped and retared with only one positioning.

The by-product plant is of the semi-direct type, designed to handle the crude gas produced from the coal carbonised at the ovens and to remove from it tar, ammonia and benzole before passing forward to the 1,000,000-cu.ft. capacity Klonne gas holder. The by-product plant comprises a cooling installation to reduce the temperature of the hot gases leaving the ovens, and exhausting plant for drawing the gases. from the ovens and delivering them through the by-product plant, an electrostatic detarring plant, a gas reheater, saturaters for recovery of ammonia in the form of ammonium sulphate, final gas coolers for cooling down the gases and extraction of naphthalene, and finally, a series of benzole scrubbers for absorbing benzole vapours from the gas by means of wash oil.

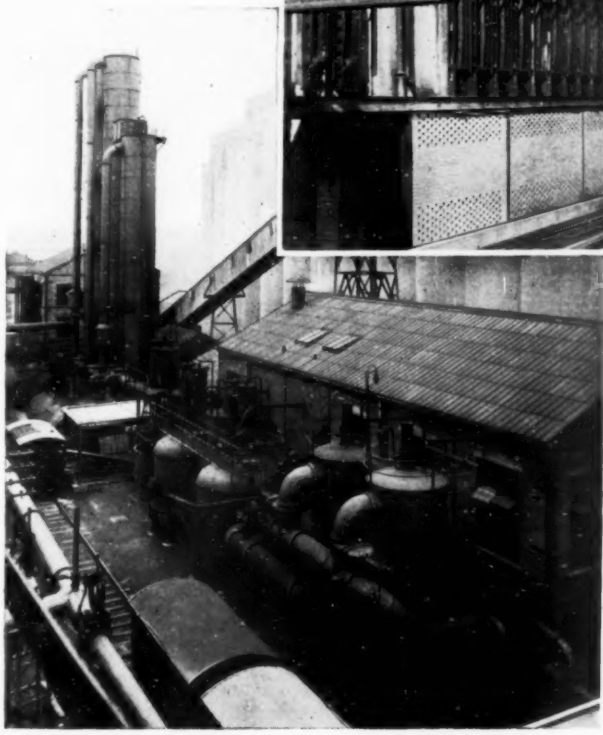
Associated with the various units are all the necessary pumps, drains and seal pots, plant for extraction of benzole from the wash oil, benzole rectification plant, storage tank farm, etc.

The gases are led from the ovens through brick-lined ascension pipes into two collecting mains (one to each battery) where they are sprayed with hot liquor and cooled down to 95–100° C. before entering the suction main. The liquor is sprayed at approximately the rate of 46,000 gals. per hour. The gases leave the connecting main under a pressure of 5 mm. W.G. controlled by Reavell Askania regulators.

There are three primary coolers of the multitubular type where the gas is cooled down to a suitable temperature by indirect contact with water, the water being counterflow to the gas. Two coolers are in normal use, one being a change-over spare. Each cooler is fitted with seal pots for collection of condensates which overflow through pipes into the tar and liquor separating tanks.



The pusher side of the coke-oven battery.



A general view of the by-product recovery plant.

The liquor flushing and separating tank is a rectangular steel tank, with a total capacity of approximately 36,000 gals., and is divided by vertical partitions into: Two settling compartments, a liquor compartment and a tar compartment. Either or both of the settling compartments can be worked at once, this to enable isolation for cleaning purposes. Suitable overflows and adjustable sleeves are provided to obtain correct separation of the tar and liquor. There are two exhausters, one operating and one spare. These are of the single stage, double inlet, Rateau " Star " turbo type, driven by direct connected single-stage Rateau turbines. Each has a maximum capacity of 900,000 cu. ft. per hour. The suction before the exhauster is kept constant by Reavell Askania governors operating on the steam supply to the turbine.

A quantity of tar and liquor is " knocked out " of the gas in passing through the exhauster and seal pots are provided which are in turn connected to a below ground level sump.

Two electrostatic detarrers of the Whessoe-Woodall Duckham type are in operation working in parallel. Normally both detarrers are in operation, but in cases of emergency either detarrer is capable of handling the whole of the gas at a slightly lower efficiency. The tar fog remaining in the gas on entering the detarrers is removed by the intense electrostatic field maintained in the detarrers. The motor generating sets associated with the detarrers consist of two high tension D.C. generators, connected in series, and driven in line by a motor through suitably insulated couplings. Two sets are provided each of which will operate either or both detarrers. Should the high-tension current fail for any reason, indicating lights and klaxon horns immediately give warning.

The reheater consists of a steel shell containing steam-radiator sections having a heating surface of approximately 435 sq. ft. The heating medium is exhaust steam from the turbines. The gas leaving the detarrers passes through the reheater, where it is heated to about 60° C. before entering the saturaters.

The two saturaters, one of which is a spare, are lead lined throughout and fitted with acid catchers on the outlet stream, these for trapping any acid liquor carried forward by the gas. A Wilton crude ammoniacal liquor still is provided and the ammonia vapour leaving the still is provided and the ammonia vapour leaving the still is passed into the main gas stream before saturater. The ammonia laden gas passes through the acid bath in the saturater, forming ammonium sulphate. The sulphate is ejected from the saturater on to one of two lead-lined draining trays each of which is fitted with two movable copper spouts. When a draining table is filled with sulphate one of the spouts is dropped into position conveying the sulphate into one of the three centrifugal driers installed. The sulphate is whizzed at high speed until it contains very little free liquor. It is then removed through the bottom of the centrifugal basket on to a rubber conveyer belt and carried into a " Wilton " type neutralising and drying machine. The drier has a capacity of 18 tons per 24 hours, and is fitted complete with elevator at the outlet end, receiving hopper and automatic bag-weighing machine.

The gas leaving the saturaters through the acid catcher passes into the bottom of the final cooler. This consists of a steel tower 9 ft. diameter and 75 ft. high filled with wooden hurdles. Water sprays are fitted in the top of the cooler, and the gas is cooled down by direct contact with water travelling in counterflow to the gas. The water overflows from the bottom of the cooler into a naphthalene separating sump. The naphthalene stripped from the gas by the water in the final cooler floats to the top of the sump and is skimmed off, drained and bagged, forming a good saleable product.

Two benzole scrubbers are provided, working in series,

These are 10 ft. diameter and 100 ft. high packed with wooden grids and fitted at the top with oil sprays and in the bottom with benzolised oil receiving tanks. The gas leaving the final cooler enters the scrubbers at the bottom and is washed in counterflow with creosote oil as the washing medium.

The benzolised oil from the scrubbers is pumped to the benzole plant which is in three sections :—The first section dealing with the creosote oil from the scrubbers consists of two heat exchangers in series, two superheaters (one of which is a spare) creosote oil still, crude benzole condenser and separator. The second section comprises a still of 6,000 gals. capacity, surmounted by a fractionating column and dephlegmator, a once-run benzole condenser and separator. This section converts the crude benzole into a "once-run" product. The residues from this still are run into a below ground-level residue tank, from which they are pumped into cooling trays. Naphthalene separates out in the cooling trays and this product is drained free of oil and bagged for sale. The oil free of naphthalene at the draining temperature is returned to circulation.

The third section is a plant for the rectification of the total once-run benzole into motor spirit and other fractions. The rectification plant comprises apparatus for the chemical treatment of the once-run benzole : a lead-lined agitator of the cyclone type fitted with a special type vortex breaker and measuring tanks for supplying correct quantities of acid and soda used in the washing operation. The washed benzole is run into a 4,000 gals. capacity still, fitted with 3 ft. 6 in. diameter fractionating column, water dephlegmator, condenser and separator. There is also installed a patent plant for dealing with the acid sludge produced in the benzole washing process. The disposal of this sludge has always been something of a bugbear. At Cardiff the sludge is run into a lead-lined tank, fitted with steam coil and containing hot water. The hot water and steam agitation cause the acid tar in the sludge to separate out in the form of hard pitch which floats to the top of the pot and is easily removed. The remaining acid liquor freed from pitch is run out into an egg and blown into the mother liquor tank at the sulphate house.

BLAST-FURNACE PLANT

The blast-furnace plant comprises three blast furnaces, each with an average output of 3,000 to 3,500 tons per week. Prior to the works being reconstructed only one blast furnace was in blast at a time, so that not only has the existing blast-furnace equipment been modernised, but provision has had to be made for handling the raw materials and disposing of the output of a plant which is producing about 10,000 tons of pig iron per week.

Raw Materials

Coke is obtained from the coke ovens and from local coke-oven plants. Both home and foreign ores are used, the home ores consisting of Llanharry, which is mined locally, and Oxfordshire. The foreign ores are obtained from Spain, the Company being interested in the Orconera Iron Co., at Bilbao and Santander. Foreign ores are also obtained from North Africa, Sweden, Newfoundland and elsewhere. Limestone is obtained from the Company's own quarry at Creigiau.

The Firm leases a portion of Roath Dock, which is connected to Cardiff Works by a private line. All the foreign ore is unloaded here by means of hydraulic cranes, the wharf also being used for unloading other seaborne traffic and for shipping the finished products. There is adjacent to the blast-furnace plant a large ore-crushing and screening plant. If necessary all ores coming into the Works can be crushed and screened. The wagons containing the ores to be crushed are delivered to an electric hoist at the crushing plant by which they are raised and discharged into the hoppers above the crushing floor. The empty wagon is lowered by a gravity drop and then passes below the plant to receive the crushed ore. From the hoppers the ores are discharged over shaker bars into one of the three jaw crushers. One of these crushers delivers on to a screen which takes out the fines. The other two crushers deliver into disc crushers which are used for very hard ores, these can be crushed down to 2 in. cube.

All the ore and limestone after weighing is raised to the gantry by means of a double electric hoist. Both hoists deliver to any of three tracks. One track passes over the bunkers so that wagons can be emptied direct into them. The other two pass on either side of the ore stocking space. Wagons can be emptied at any point on these two tracks, and the ore falls down a chute on to a travelling distributor belt. There are two of these distributor belts on each side of the stocking space and they can be positioned under whichever chute is being used. The belts deliver the ore about one-third of the way across the stocking ground. The ore stocking space is spanned by a Stothert and Pitt ore transporter with a 12-ton grab. This grab delivers into a transfer car running on a second track over the bunkers. All tracks are inclined so that wagons run by gravity from the hoist to the drop.

Coke from the coke ovens and purchased coke is brought to the coke bunkers by means of a rubber belt after the coke has been screened at the central coke-screening station.

The three blast furnaces are 87 ft. high and have hearth diameters of 16 ft. and are designed on American lines. Each furnace consists of a steel shell which is supported by steel columns. The hearth jackets are riveted steel plates and are sprayed with water on the outside. No. 1 furnace has a copper cooled bosh, whereas the other two furnaces have spray boshes. Cast-iron coolers are fitted in the stacks and around the stacks are galleries to give easy access to same. Each furnace has ten tuyeres and two slag notches. Charging is done by means of a scale car and double-skip charging gear. The inclined skip bridge is supported independently of the furnace. The bunkers are fitted with double-lip gates which are opened by means of a compressed air cylinder on the scale car. Each furnace is fitted with a standard McKee top which gives very good distribution. There are four bleeders on each furnace, and off each bleeder there is an offtake which leads into a downcomer there being two downcomers to each furnace Each downcomer leads into a Vortex whirler, the gas after passing through a whirler goes into a dirty gas main and then to the gas-cleaning plant.

Hot-Blast Stoves

There are nine stoves each 95 ft. high by 24 ft. diameter, each furnace using three stoves. The stoves are fitted with the Hotspur system of chequering, which gives a very high efficiency. The stoves are fitted with Steinbart automatic combustion-control burners. There is also installed on all the furnaces an automatic blast-temperature control apparatus in order to obtain a uniform blast temperature.

All the pyrometers and other instruments for the three furnaces are in a central instrument house and are so arranged that they can be seen through the windows without the necessity of going inside. All the furnaces have the usual series of pyrometers and pressure gauges. Two items of interest are automatic stockline controllers and recording pyrometers showing the temperature of the blast furnace stack at various places.

The furnaces are provided with pig beds which are spanned by overhead cranes and also with a hydraulic pig breaker, but these are seldom used. The greater part of the iron is taken molten to the steelworks in mixer-type ladles of 60 and 120 tons capacity. The remainder of the iron is passed over a double-stage pig-casting machine. The slag is disposed of in ordinary ladles and tipped part to a dump on the foreshore and part to a Tarmac Plant.

Blowing Equipment

The blowing equipment comprises—one Fraser and Chalmers Impulse multi-stage type turbine driving a single-flow type blower, delivering 50,000 cu. ft. free air per

minute, against a pressure of 15 lb. per sq. in., complete with surface condensing plant; two 5-stage high-pressure Curtis type turbines driving 3-stage double inlet blowers, delivering 42,000 cu. ft. free air per minute, against a pressure of 15 lb. per sq. in., complete with surface condensing plant and two Parsons reaction turbines, driving blowers, each delivering 38,000 cu. ft. of free air per minute against a pressure of 15 lb. per sq. in., complete with surface condensing plant. The last two turbines serve as reserve units.

Gas-Cleaning Plant

This is a two-stage electro-filter by Lodge Cottrell, Ltd. The normal working load of the plant is 8,000,000 cu. ft. per hour at 15° C. and 30 in. Hg., but for short periods an overload up to a total throughout of 10,000,000 cu. ft. per hour is permitted. The main immediately before the cleaning plant is 10 ft. 6 in. diameter and serves as the common collecting point for the gases from three blast furnaces. Two branch pipes, each 8 ft. diameter, emerge from the common main and form water seals immediately before the pre-coolers. The gas flow in the precoolers is from top to bottom, and the system of cooling and liminary dust removal is carried out by means of water preflushing nozzles arranged near the top of each tower. The flow of water through the nozzles is governed by Askania temperature regulators, which operate in conjunction with thermostats fitted into the gas mains after each cooler, so that a constant gas temperature is maintained at these positions. The most suitable gas temperature is found to be 93° C., the usual range of temperature under working conditions being 92–94° C. Approximately 50% of the dust left in the crude gas, after the Vortex dustcatchers, is removed in the pre-coolers. The cooling water is run into a Dorr Thickener where the thickened slurry is removed and pumped into tanks for disposal. The clarified water is cooled in chimney coolers and recirculated through the plant.

The outlet mains of the pre-coolers are 7 ft. diameter and include water seals. These mains converge into a 10 ft. diameter hoppered distribution main. The pretreaters are 48 ft. × 19 ft. × 34 ft. high. The bottom of each chamber is made as a continuous hopper, whilst the uppermost rectangular portion is fitted with collecting electrodes arranged in six banks. The discharge electrodes consist of special square section wire, slightly spirally twisted.

Mechanically perated rapping gear is provided to dislodge the collected dust, whilst a conveyer of the Redler type, driven by a 2 h.p. motor removes the dust from the hoppers into a rotary seal which serves to prevent the escape of gas from the treater while dust is being discharged. The discharged dust falls into a spiral mixer where water is added to produce a slurry of the desired consistency. The treaters and hoppers are heat insulated in order to prevent the temperature of the gas decreasing below the dewpoint. The temperature of the gas after the pre-treater is approximately 70° C.

The gas passes from the four pre-treaters via 5-ft. diameter pipes to four final coolers, where the gas is cooled to a temperature of 5° C., above the temperature of the cooling water. The cool gas temperature is usually 22–26° C. Each cooler is 65 ft. high and 14 ft. diameter. Five separate gratings of timber slats are fitted in each cooler, and the flow of gas and water is counterwise. Eight cooling water distributors are arranged on top of each tower, there being separate valves to the flexible hose connections.

The four fine treaters are similar in design to the pretreaters except that the dry dust hoppers are dispensed with as the residual fine dust in the gas is deposited on the collecting electrodes in a wet condition and is washed down at intervals by sprays positioned above each bank of electrodes. Each treater is 32 ft. long × 16 ft. wide × 26 ft. high, and contains three banks of discharge and collecting electrodes. The wash-down water overflows from water seals under the treaters to the Dorr Thickener. Each of the cleaning units is equipped with an Aerex Fan driven by a 125 b.h.p. 400 volts three-phase variable-speed induction motor with range 1,440–1,225 r.p.m., which delivers clean gas into the holder main at a pressure of 8 in. to 11 in. W.G.

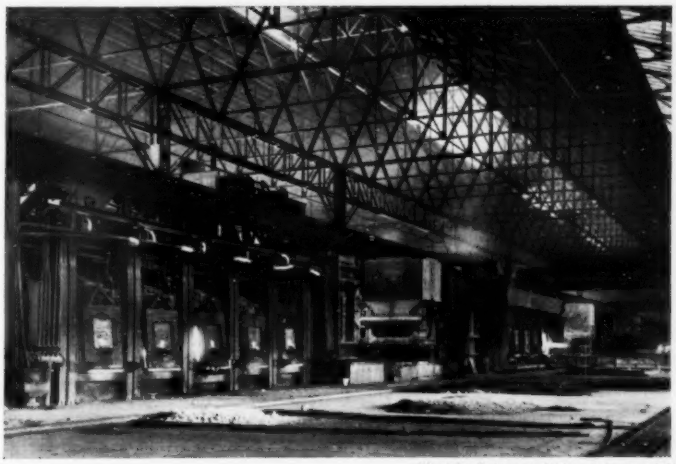


Photo by Britton and Cox, Ltd., Cardiff.

Part of open-hearth melting shop.

Butterfly valves are fitted on the outlet of each fine treater before the fans. These are operated by an Askania low-pressure regulator, which can be set at any desired minimum pressure from connections at the outlets of each fine treater. The valves will then close and isolate the fan from the treater should this fixed minimum pressure be attained and thus serve to prevent air being drawn into the treaters.

The control room is divided into two sections. Housed in one section are seven Lodge-Cottrell oil immersed precipitation transformer sets, seven synchronous rotary rectifiers and high-tension switches. Each set is in a screened enclosure consiting of wire-mesh screen with automatic-door earthing switches. Six sets are normally in operation at the same time, the spare set may be switched in to the circuits of either of those of the six in operation, if desired. There is an instrument panel in the other section on which is fitted Foster temperature recorders, Allen West pressure and gas volume recorders, Evershed and Vignoles gas holder stock recorders and indicators. Daily continuous records of temperatures and pressures at various points on the plant are under the immediate observation of the control house attendant. The gas volumes passing through each uuit are recorded as also is the total volume of the cleaned gas.

MELTING SHOP

The melting shop was designed as an integral part of a balanced iron and steel works, in which the only fuel to be used for steel production should be the by-product gases from the coke ovens and blast furnaces. Flexibility was also kept in mind, and to this end a battery of five modern Morgan gas machines were installed. This is definitely an emergency gas plant, and apart from the actual start of the steel furnaces for the first two weeks it has been shut down, but arrangements are made for a quick start in emergency. The plant operates on a mixture of blast-furnace and coke-oven gas of about 220 B.th.u./c.ft.

The furnaces are contained in a very well-designed and lighted-steel building made and erected by Lysaghts, Bristol, and which has a total length of 1,055 ft. and is 147 ft. wide. There are three tilting furnaces, 200 tons capacity, a 600-ton active mixer, built by Duncan Stewart-Demag and two fixed furnaces built by Guest Keen Baldwins of usual fixed-furnace construction.

Photo by Britton and Car, Ltd., Cardiff.

Part of casting shop with one of the casting pits on the right.

The mixer has a length over chills of 59 ft. and at foreplate level is 50 ft. long by 18 ft. wide and is 6 ft. 7 in. in depth on the centre line. The chills joining the furnace body to the ports are of hæmatite with seamless steel pipes cast in. There are five doors on the charging side and two on the tapping side for inspection and fettling. All doors and door frames are water cooled, the doors being operated hydraulically. The mixer is mounted on two roller paths built of steel plates and sections heavily braced together, the rollers being held in a spaced cage. Tilting the mixer is accomplished by steel-rack gear and pinions operated by an electric motor of 180 b.h.p. This mechanism is fitted with a "dead man" pedal and is so arranged that the furnace returns to dead centre if pressure on the pedal is released. The mixer is equipped with Friedrich removable intermediate ports which are water cooled on the nose of the port only. The regenerator chambers are steel cased and are insulated, firstly, next the plates by diatomaceous earth, then by a standard 9 in. × 4½ in. × 3 in. insulating brick. Air spaces are arranged between the gas- and air-chambers and also beneath the bridge wall separating the regenerator from the slag pockets. These air spaces are cooled by a free supply of air admitted through various ducts. The mixer hearth is built of magnesite bricks, on top of which a working hearth of dolomite is fitted on.

The reversing-valve system which is of the same design for both tilting furnaces and mixer is a composite one, consisting of water-sealed gas inlet valves with exhaust valves of the water-cooled sliding-damper type. The air valves are machined cast iron. Atmospheric or pressure air can be used at will. The furnaces are fitted with a three-port mixing valve, one port for producer, blast-furnace and coke-oven gas respectively. Under normal conditions the producer valve is not used. The amount of blast-furnace or coke-oven gas is varied by the hand manipulation of the control valve for each gas; by this means gas of any desirable B.th.u. value may be used. Each valve has its accompanying meter, and the regenerator temperatures are recorded for each chamber on a four-point recorder, the pyrometers being of the radiation-optical type. The draft on each chamber is recorded continuously. There is no apparatus installed for automatic reversal of furnaces, but instruments and recorders are generously applied and the furnaces are definitely run by the aid of such instruments, the control remaining the responsibility of the furnaceman. Waste-heat boilers (fire tube) are attached to all the furnaces and mixer, the normal amount of steam raised being 20,000 lb. per hour for the tilting furnaces and 10,000 lb. per hour for the small furnaces and mixer. The fans for the waste-heat boilers are driven by variable-speed motors.

The tilting furnaces are essentially of the same design as the mixer, having intermediate interchangeable ports, air-spaced and insulated regenerators, electrically-operated tilting, the same design of control and reversing valves, and are fitted with the same instruments and pyrometers, etc. The length over chills is 56 ft., and the size of the hearth at foreplate level is 46 ft. 8 in. × 14 ft. 5 in., and the depth of hearth is 3 ft. 7 in. The furnace hearths are of magnesite brick with a working hearth of dolomite on top.

Hot metal from the blast furnace is brought to the mixer in 120-ton mixer-type cars, which discharge the iron into transfer ladles of 45 tons capacity; these are lifted through a hatch in the floor and the iron discharged into the mixer through the usual hot-metal chutes. Iron from the mixer is discharged on the casting side into a ladle on a transfer car, which passes under the mixer and is lifted through another hatch for charging into the steel furnaces; this arrangement ensures that the charging of mixer or furnaces does not interfere in any way with the tapping of the steel. All charging is kept to the charging side of the shop.

The shop is equipped with two 60-ton overhead cranes and three ground-type revolving chargers on the charging side, and one 120-ton and two 150-ton casting crane on the tapping side. The test pieces are sent by pneumatic tube to the main laboratory. The ladles are of 80/90 tons capacity and have two stoppers and are heated with blast-furnace gas at a central station in the casting bay. Teeming is done from the cranes at four teeming stages, and at one fixed stage with hydraulic pusher for the ingot car. After pouring the ingot, mould cars are transported to the stripper house, which is situated between the steel plant and the mills. There are two overhead-electric strippers. After stripping, the ingots continue on their way to the mills on the mould cars. Here the ingots are lifted by overhead ingot cranes and placed in the soaking pits. The empty mould cars then return to the stripper shop where they are re-set and then returned to the casting bays.

The handling of scrap, ore, limestone, etc., has received very careful consideration. There are two scrap yards—one for heavy and one for light scrap. In the latter is installed a bundling press of the latest design. For charging the scrap into the receptacle for this press the cranes serving it are provided both with magnets and grab buckets. The scrap from the stock yard is brought along in charging boxes on bogies up a ramp on to a platform alongside the charging bay. This platform has three tracks, two for marshalling the bogies and another for charging.

At the north end of the shop are installed bunkers for receiving ore, limestone, lime, dolomite, etc., from drop-bottom cars. In order to bring this material up to the furnaces there are used a number of moveable bins each taking 25–40 tons, which are handled by the overhead 60-ton cranes in the charging bay. The bins are filled from the above-mentioned bunkers and placed on stands between the furnaces. From these bins the charging boxes are filled through pneumatically-operated gates. Ore and limestone etc., is, therefore, always available when required without delay, leaving the tracks outside the charging bay free for dealing with scrap only. At the north end of the plant are also crushers and grinding pans for alloys and cements.

British Columbia Nickel Ore for Japan

A shipment of 500 tons of picked ore, assaying between 4/5% nickel and about 2% copper, is reported to have been sent to Japan from the property of British Columbia Nickel Mines, Ltd., at Choate, B.C. This is a test shipment, which will be treated in Japanese smelters with a view of the possible establishment of a regular market for the products of the British Columbia nickel mine.

Bronzes in Machine Construction

By JOHN D. WATSON

Various grades of bronze are now available; each has a more or less defined purpose and, when correctly proportioned and compounded with additional alloying elements such as manganese, nickel, silicon, etc., have widely different properties. In this article some alloyed bronzes are discussed which are of value in various forms of machine construction.

IT is not so many years ago since the mechanical engineer had to rely on non-ferrous metals of doubtful composition and of no great strength, for those machine parts which call for bronze in one form or another. Classified under the general heading of gunmetal, machine bronzes of a decade or so ago were for the most part the product of the back-street foundry, and if some were good, others were definitely bad.

To-day, with metallurgy something of an exact science, not only are various grades of bronze available to British Standard Specification, but each has a more or less definite purpose and, like modern steels and cast irons, when alloyed with manganese, nickel, silicon, etc., and correctly proportioned as to the tin, copper and phosphorus content, have widely different properties of strength, resistance to heat, wear and corrosion, and vary as to their suitability for casting, machining and hot- or cold-working as the case may be.

Bronze, in its general classification, is a copper-tin alloy and the art of casting it appears to date back at least 4,000 years, and up till comparatively recent times the best all-round composition was the 88 : 10 : 2 Admiralty gunmetal which, as its name implies, was largely used in ship construction. Varying the tin content hardens or softens the metal, whilst the small proportion of zinc improves it from the founders' point of view.

The inclusion of manganese adds strength and resistance to corrosion, and nickel, in general, adds toughness and resistance to wear. In addition there are those valuable copper-nickel alloys commonly known as Monel metal, a comparatively new material of this class with the addition of aluminium known as "K" Monel metal and the relatively cheap silicon-copper alloys.

Silicon Copper

This material is a copper-rich alloy of the solid solution type, principally of value in producing good cheap castings for hydraulic work and being suitable for bolts and fastenings. It is non-magnetic, works well, has a high-tensile and high-fatigue limit rendering it very well suited for bolts and fastenings in electrical and hydraulic work. In its wrought state the material is ductile, and it is not damaged if stressed to the yield point. This merely results in a slight permanent extension with some loss of ductility but this has a beneficial effect upon the proportional limit as this is raised to the overstressed value without any loss in tensile strength.

The latter reaches 98,000 lb. with a yield point of 80,000 lb., elongation in 2 in. 18·8%, shear stress 60,000 lb., reduction of area 57½% and Brinel hardness 167. Obviously these properties will show up well in bolts which offer quite exceptional resistance to shock. The brittleness of bronze and brass bolts has to be provided for by generous proportions, but actually under test, bolts of this material, ¾ in. diameter 10, T.P.I. have shown a safe load of over 3,000 lb. This is comparable with the strength of a good forged-steel bolt, double that of phosphor bronze and about five times that of ordinary gun-metal.

For general hydraulic, electrical and marine castings, whilst not possessing the properties of the high grade nickel bronzes, this metal, containing approximately 95·4% copper, 3·5% silicon and 1·1% manganese gives a close dense-grained casting without any trouble to the founder when quickly melted and poured into well-gated moulds and being very fluid it gives well-defined castings of thin section, easy to machine after being annealed. This latter operation also toughens the metal and gives added resistance to pressure. Being free from tin, this alloy is, of course, relatively cheap.

Copper-Tin Bronzes

There are at least half a dozen straight copper-tin bronzes which are of value to the engineer. They vary in composition from the 88 : 10 : 2 copper : tin : zinc composition of Admiralty gunmetal to 86 : 14 copper-tin, the increase in the tin content raising the hardness till at 15% the metal becomes excessively brittle. Above 10% the tensile strength decreases but there is an increase in resistance to wear. Furthermore, phosphorus up to about 0·3% gives fluidity in the molten state while zinc is a deoxidiser. Phosphorus also hardens the metal, though at the expense of brittleness.

The inclusion of lead, whilst undesirable in some instances, is valuable in bearing metals as it gives plasticity, and metal containing up to 12% of lead will make good bearings with a low coefficient of friction and will bed down well in the minimum of time. Nickel in proportions up to 1% refines the grain and gives a tough strong alloy. It is usually an essential inclusion in centrifugal castings for gear blanks and of leaded bronzes for bearings.

Where Cheap Materials Fail

The actual production of high-grade bronze castings and especially those produced on the centrifugal system is definitely the metallurgists' and founders' job, and there is everything to lose by buying them down to a price of experimenting in the foundry. The copper itself in the first instance must, for good material, be 99·9% pure electrolytic. Scrap copper wire though initially pure offers a relatively large surface to oxidation, resulting in gas absorption which is even more apparent in tinned copper wire where the tin is converted to oxide prior to the material being melted. It is gas absorption and oxide inclusions which are the main cause of porosity and weakness. Cheap material from doubtful sources is very often made from scrap trolley wire and old firebox copper. The first often contains cadmium which was added to harden it and this affects the phosphorus content, whilst the arsenic and sulphur in firebox copper are definitely harmful. Then again, as regards tin, good metal can only be made with tin of high purity, which is costly. The principal impurity of the cheaper grades is lead and though lead is, as already stated a beneficial inclusion in certain grades of bronze it must not be present in the tin because this indicates the presence of such impurities as arsenic, antimony and bismuth. The lead has to be added in the form of virgin pig lead of guaranteed purity, because remelted scrap contains antimony; likewise the zinc must be at least 99·85% pure, and the same remarks apply to the phosphor tin or—more usually—the phosphor copper which is added when phosphorus is included, the low-grade material having impurities which affect the metal as a whole.

Nickel Bronze

Whilst nickel bronze is a somewhat difficult material to cast and is only suitable for a foundry with complete metallurgical control, it is proving one of the most useful materials of the non-ferrous group in modern mechanical

work. The 88·25 : 10 : 5 : 1 copper-tin-nickel gives a strong, hard, tough and good-wearing casting in sand: it is the 88 : 11·2 : 0·5 composition which is extensively used for centrifugally-cast gear blanks, whilst the 81·7 : 12·5 : 1 metal with 5% of lead which, as already stated, provides a plastic hard-wearing heavily-loaded bearing metal, though, for lighter work, 8% of lead and 10% tin is generally the more suitable for unlined bearings and 88 : 4 : 6 copper-tin-zinc gives a good casting to resist shock and which tins well. A good general purpose hydraulic metal is a leaded phosphor bronze of 84 : 8 : 4 : 4 copper-tin-lead-zinc, provided the water is not highly corrosive, but there are other compositions which are better suited to acid and corrosive conditions.

So far as those copper-tin alloys which are modified by small—usually not exceeding 1%—addition of nickel are concerned, the nickel inclusion has a marked influence in its strengthening and toughening action, tension, compression, yield point, ultimate strength and resistance to compression being raised by successive additions of nickel and up to 3% there is no appreciable loss of ductility, but with the high tin content the mixture is sensitive to pouring temperature which is affected by the nickel and the latter does not usually exceed 2%.

Apart from improving the physical properties, nickel additions result in a slight increase in the melting point, about 6° C. per 1% of nickel content when the latter replaces copper and 18° C. when it replaces tin and the fluidity of the metal is improved. Normally the foundry difficulties are not much increased with the addition of nickel, but the pouring temperature has to be very carefully controlled, and if this is done, any nickel-bronze casting will prove dense and free from shrinkage cracks. This is a valuable property in hydraulic pressure castings. The grain, too, is refined and in the case of leaded bronzes, the troublesome segregation of the lead is reduced by 1% to 1½% of nickel. It causes the metal to set rather more rapidly on entering the mould and increases the solubility of the lead to almost double the amount of pure copper which can only dissolve 35% of lead at the best.

Centrifugally-cast worm-wheel blanks provide a very good example of the remarkable properties of 88 : 11·2 : 0·3 : 0·5 copper-tin-phosphorus-nickel composition. This material has a yield point of 13–15 tons, a maximum stress of 18–22 tons, elongation 9–12% and Brinell hardness 90–100. It has extraordinary ductility as shown by the ability of these castings to be bent into a U-shape without cracking.

In the matter of leaded-bearing metal, an 80·7 : 10 : 8 : 0·3 : 1·0 copper-tin-lead-phosphorus-nickel composition has been found specially suitable to run against semi-hard rings, the metal being plastic and compensating for slight inaccuracies in fitting and with its low coefficient of friction the metal runs cool at the highest speeds and whilst resistance to abrasion is somewhat on the low side, the toughness and softness of the metal resists any tendency to crack under shock loads. In the sand-cast condition this material has the following properties :—

Yield point	10—12 tons per sq. in.
Maximum stress	14—17 ,, ,,
Elongation	6—12%
Brinell hardness No.	65—75
Izod impact value	80—90 ft.-lb.
Density	8·5—8·75

Furthermore, the metal retains its properties at relatively high temperatures, and this can be increased by adding up to 7% nickel to 11% tin. In this respect the material is much superior to Admiralty gunmetal of 88 : 10 : 2 composition.

Resistance to Corrosion

That bronze itself is non-corrodible, is quite a mistaken idea. A.G.M. and some other straight tin bronzes stand up to sea water pretty well as that was their original purpose, and other compositions have already been alluded to as being good hydraulic bronzes, but that presumes them to be in contact with clean fresh water. Corrosion in its general sense and especially that due to acid or sulphur compounds ought to be met by a definite grade of corrosion resisting bronze such as the 85 : 5 copper-tin base composition. Some of these metals including the cupro-nickel alloys are of more interest to the chemical engineer than the machine constructor and are used extensively in the brewing, dyeing and allied trades, but there are many conditions under the present heading which call for material which will stand up to heat and corrosive elements at the same time, possessing and maintaining their strength under such conditions.

For instance, the metal referred to above with a specific gravity (cast) of 8·62 has an ultimate strength of 21 tons, reduction of area 34%, elongation in 2 in. 39%, though with a Brinel hardness of 72 it is soft. On the other hand, the drawn rod has something like double the strength, and is twice as hard. Furthermore, both grades maintain their strength at high temperatures, the cast bar showing 20 tons tensile at 1,000° F. as against 5·2 tons for 87 : 10 : 3 gunmetal and 9·40 tons at 750° F. for 86 : 13 : 0·25 phosphor bronze, whilst manganese bronze drawn rod though strong at normal temperatures, has barely 3 tons tensile at that temperature. The 85–5 copper-tin base metal is therefore suited to high-temperature work such as valves for superheated steam and its resistance to corrosion renders it suitable for pump valves and components of oil machinery and in others where destructive sulphur compounds are met with which, in common with high temperatures, are destructive to most bronzes though they may have excellent mechanical properties.

Under the present heading too, come the high nickel content bronzes. By the use of relatively high nickel percentages, alloys are obtainable, which, while having structures typical of bearing metals have much superior corrosion-resisting properties and are very useful for such exacting work as the working faces of sluice valves and plain—non-roller—sluices, especially those in contact with sea water and other waters of a corrosive nature. Metal with a 60 : 30 : 8 : 2 copper-nickel-tin-iron content is frequently used for valve facings. It has a maximum stress of 30 tons and a Brinel hardness of 241 ; a similar composition is used for sleeves in contact with stainless steel spindles. In the latter instance the alloy is compounded to give a low coefficient of friction combined with high-tensile strength so as to be suitable for Acme threaded sleeves and some pump builders use it for the neck rings of centrifugal pumps.

Some high nickel content bronzes would, of course, approach in composition and physical properties cupro-nickel alloys such as Monel metal, which is outside the scope of these notes, but generally speaking alloys with over 40% nickel will resist both heat and corrosion and are of considerable value to the steam engineer dealing with the high-pressure and high-temperature steam. They will show up to 20 tons tensile at 1,100° F. and have all the properties which render them suitable for high-temperature valve work.

Rich Deposits of Minerals found in Urals

Large deposits of ore containing copper, sulphur, gold and silver have been discovered in Blyava not far from Orsk in the Urals, where the construction of a copper and gold combine is now well under way. The deposits are estimated to contain several million tons of ore, far exceeding the deposits of Karabash, the well-known copper-mining area of the Urals.

New rich beds of tungsten, a rare metal used in the manufacture of special steels and hard alloys have been found by the geological prospecting expedition under Professor Smolin in the southern Urals and in Bashkiria.

Recent Advances in the Aluminium Industry

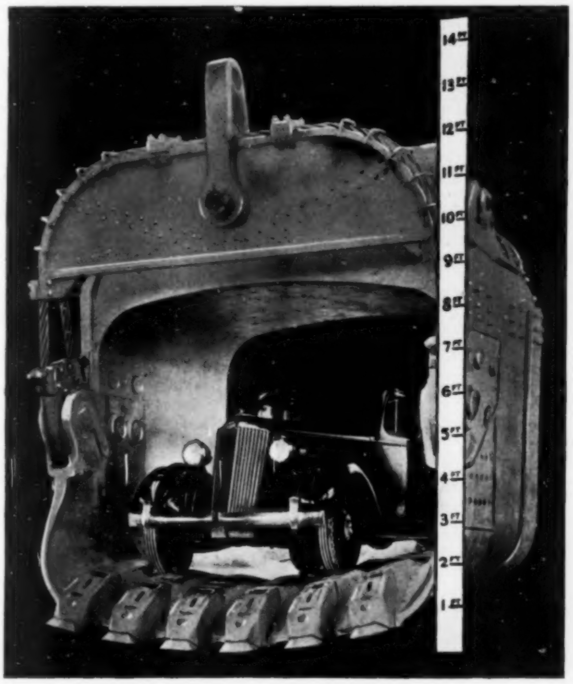
Progress in fabricating technique has increased the use of aluminium alloys possessing superior properties, states Mr. F. C. Frary in a recent address before the Electrochemical Society; new equipment and increased knowledge have also permitted the production of larger structural shapes, forgings, special extruded shapes and tubing. This article gives an abridgement of the advances discussed.

THE most important advances made by the aluminium industry during recent years are connected with the use of the metal and its alloys. They permit the metal to enter and compete in new fields of usefulness, by virtue of improvements in alloy composition, fabricating methods, or methods of design and construction. These advances have been brought about by an intensive technical study of the fundamentals in these three fields, and because of them, the usefulness of the metal is being considerably extended.

When the strong alloys of the duralumin type were first commercialised, their physical properties were so different from those of the alloys which the industry had been accustomed to fabricate, that the available equipment and technique were quite inadequate. Rolling mills were not heavy enough, ingots not good enough, and the technique of eliminating defects was undeveloped. For a good number of years both the character and size of the parts made were decidedly limited by these manufacturing difficulties, and such changes of composition as would increase the strength of the alloy were impossible in practice, because of fabricating difficulties. Intensive investigation and the accumulation of manufacturing experience, including improved equipment, have now very largely reduced these difficulties and made it commercially feasible to manufacture stronger alloys of this type. The increased strength is obtained by changing the amounts of certain of the alloying constituents. These improved alloys sprang into immediate popularity with industries such as aircraft manufacture, where each increment of strength is important. They have largely replaced the older alloys of this type in the modern types of aircraft.

Another type of alloy in which modern fabricating methods have played a great part is the series of aluminium-magnesium alloys, examples of which were first introduced many years ago under the name of "Magnalium." When introduced, they were commercially unsuccessful because of high fabricating costs and other difficulties; now, however, after many years of improvement in technique, brought about by the necessity of working the duralumin-type alloys, such alloys have come within the range of commercial manufacturing ability, and several of them are likely to become very important. Alloys containing from 2 to 5% of magnesium with high-grade aluminium are characterised by good resistance to corrosion under salt-water or salt-spray conditions, and also by a very high endurance limit. They combine with these properties the highest strengths attainable in any non-heat-treated aluminium-base wrought alloys, and have good ductility and weldability.

For many years the duralumin-type alloys have been used to a small extent in the manufacture of screw machine products, but the long curling chips produced in machining have been a serious drawback in the manufacture of many articles. Recently a new group of free-cutting strong aluminium alloys have been introduced, which in a screw machine give the same short chips as free-cutting brass, and may, in fact, be substituted for the latter material without change in speed or tool set-up. With good resistance to corrosion and their light weight and white colour, they promise to open up a wide field of usefulness for aluminium.

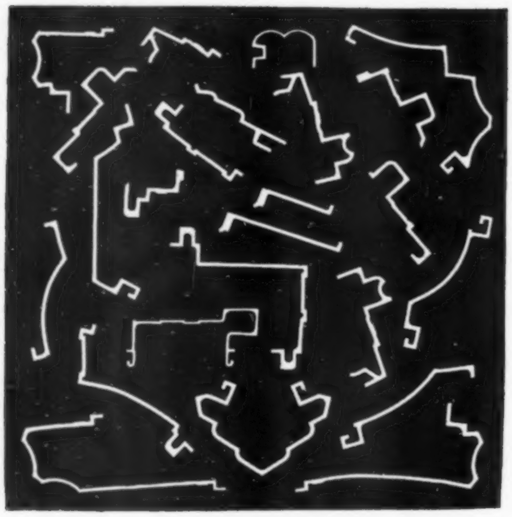


A large aluminium alloy structure for a mechanical shovel.

The aluminium-magnesium alloys have also been found adaptable to many purposes in the casting field. Alloys containing about 4% of magnesium are particularly good in their resistance to rather severe corrosive conditions, while alloys containing about 10% of magnesium develop the highest strength of any of our present aluminium casting alloys and have given a very good account of themselves in practice. Both types have been introduced commercially within the last few years.

The heat-treated aluminium-copper casting alloys introduced into this country shortly after the War have been supplemented by heat-treated aluminium-silicon alloys containing small amounts of magnesium, to cover another field of demand for castings. The use of aluminium-silicon alloys for die-casting has very largely increased the scope of this process, because of the superior casting qualities of these alloys.

One of the outstanding recent advances in the field of fabrication is the provision of equipment for making large wrought articles. Structural shapes as much as 85 ft. in length, and ranging in size up to 12-in. channels, are currently produced in strong aluminium alloys of the duralumin type. Large strong alloy plates in thicknesses of ¼ in. up to 2 or 3 in. may now be obtained in widths as great as 120 to 130 in., and lengths up to 35 ft., subject only to the limitation of a maximum weight of 2,000 lb. per piece. This represents a tremendous advance from the position shortly after the close of the War, when only



Cross section of assorted extruded aluminium sections.

thin and small sheets were obtainable and the maximum weight for a single piece was well under 100 lb.

Another fabricating proplem presenting many difficulties for some years was that of producing even small-sized tubing from the strong aluminium alloys. The advance in the art now permits the production of all sizes of round, square, oval or streamlined tubing of this sort up to about 11 in. diameter. Only those who struggled with the early orders for a few pounds of small round tubing can appreciate the advance in technique which this involves.

Many of the complicated shapes required by the architectural field and in the manufacture of strong alloy structures are produced to-day by the extrusion process, which fifteen years ago produced only relatively small and simple shapes. Improved technique has not only increased the size and complexity of the available shapes, but has decidedly improved their quality and lowered their cost.

One of the major fabricating developments is the production of the compound strong alloy sheet. By properly preparing and rolling a composite ingot, a sheet is obtained comprising a strong alloy core covered and protected by a very thin layer of special purity aluminium integrally bonded to each surface. Not only are the strong alloy surfaces physically protected by the more corrosion-resistant pure aluminium, but there is also a very valuable electrolytic effect, protecting cut edges, rivets, scratches, etc. Such material is particularly advantageous in the thin and highly stressed materials required in the aviation industry, and has met with increasing acceptance within the last six or eight years.

The development of the technique of forging large, strong alloy blanks, out of which aeroplane propellers could be machined, resulted not only in an increase in business for the aluminium fabricators, but also in a decided increase in the allowable power per aeroplane engine and an increase in the ruggedness and reliability of the propellers themselves. Other forgings, ranging in size up to locomotive side rods, have given the strong aluminium alloys an opportunity to enter many fields. Recently, hot pressing, which is in many respects similar to forging, has proved particularly advantageous for highly stressed aeroplane pistons and other similar parts.

Another line of progress is the oxide coating of various aluminium articles. For many years the anodic oxidation of aluminium in phosphate or borate electrolytes was used to a limited extent in condensers and similar articles. Subsequently the use of chromic acid electrolyte was found to produce a thicker and stronger coating which was especially well adapted to serve as a basis for paint in the protection of aircraft structures. Finally, anodic oxidation in sulphuric or oxalic solutions has enabled us to put on still heavier coatings, and a variety of treatments make it possible to control the absorptive powers of these coatings so as to be able to cause or prevent the absorption of dyes, pigments, corrosion inhibitive chemicals, etc., at will. The superior hardness and abrasive resistance of these modern oxide coatings have given them a well-deserved popularity among the users of aluminium articles.

The most recent advance in this line of anodic treatment is the electrolytic brightening process, which is unique in that a drawn and buffed aluminium surface having a reflectivity of about 70% of light, after an electrolytic brightening treatment and oxidation, lasting as long as 30 mins., still retains its specular character, and has increased in reflectivity to about 85%. The oxide coating protects it against weathering and scratching from moderately careless handling or cleaning, and the resulting reflectors bid fair to displace present-day reflectors in most fields where quality is of much importance, and where silvered glass does not meet the conditions.

A recent advance in the finishing art is the successful coating of wrought articles such as buckets, bobbins, etc., for the rayon industry, with sythetic resin coatings, which not only satisfactorily resist successive immersions in weak acids and weak alkalies, but also are sufficiently flexible and well enough anchored to the metal to withstand the rough treatment that such equipment gets in factory usage.

With its lower modulus of elasticity, aluminium does not fit into the design formulas used for steel, even though its strong alloys have strengths and elongations comparable with those of ordinary steel. Moreover, its higher price and the fact that it is generally used for structural purposes only where the factor of weight-saving is of great importance bring much pressure to bear on the designer for more accurate and economical use of material. In order to supply the necessary fundamental information required for the economical and satifactory design of aluminium structures, fundamental experimental investigations and the development of properly derived design formulæ and design standards have been necessary. This work has been actively pushed and is still going on. It has already reached the point where it has been of very great value to the designers of aluminium structures, and where it is able to contribute to general structural theory. It is safe to say that in the end this will not only provide an increasing market for aluminium, but also react favourably upon structural design in steel and other metals, to the general advantage of the public.

Torch and hammer welding, which were the only means available, have been supplemented by spot welding, electric seam welding and arc welding. Many other minor but important developments have been made, and are being made, which facilitate the production of articles and structures of all types of aluminium alloys. Progress along all of these lines will undoubtedly continue, and bring about an increasing adaptability and commercial efficiency of this metal, which this year celebrated the fiftieth anniversary of its commercial birth.

Big Blasting Operation in U.S.S.R. to Uncover Copper Ore

WHAT is claimed to be one of the biggest blasting operations is to be carried out at the Kounrad copper ore deposits to uncover the rich layers of copper ore, which will serve as the raw material for the Pribalkhash Copper Flotation Combine. As much as 2,070 tons of explosive substances are to be used for this operation, which will take place in January next. All preparations are practically completed. The Seismological Institute of the Academy of Sciences of the U.S.S.R. is being asked to make scientific observations of the explosion.

Electroplating Plant and Practice

In this article is given a brief description of the plant and practice at the Works of the Société pour la Fabrication des Projecteurs Electriques Marchal, recently visited by members of the Institute of Metals.

AT the works of the Marchal Headlights Company, nickel, chromium and cadmium plating are applied in the manufacture of car head-lights, and the Company have fitted the shops on modern lines so that they are equipped to deal with new manufactures. It is noteworthy that the polishing of rotary parts is carried out on automatic polishing machines. These machines are fitted with discs of appropriate shape, comprising an assembly of cloth clamped between two flanges. A special shop is fitted for preparing the discs, and, in order to ensure the longest possible life for each tool, the best conditions, with regard to temperature, moisture and ventilation, are observed.

A few operations are carried out on Kelm and Daniel automatic machines; other machines, shown in Fig. 1, are specially adapted for "Marchal" processes, which have been devised and developed by their research department and constructed in their workshops. They are applied more especially to polishing and touching up reflectors, which is a particularly delicate and accurate task.

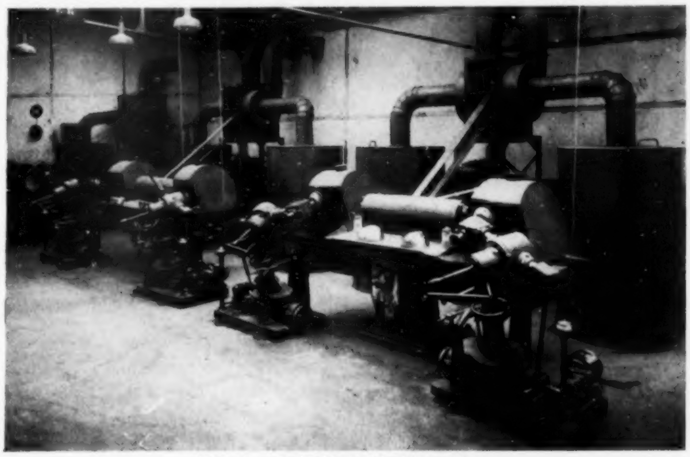


Fig. 1.—Polishing Machine Shop.

In order to take advantage of "flow production" it became necessary to use these machines in the electrolysis shop in the vicinity of the baths. This requirement in turn demanded another: Removal of the dust set up by polishing and brightening up. This problem has been solved by using individual exhausting devices on each polishing machine, each of which is fitted with two dust-extraction cyclones and two fans coupled to the same shaft. This system of extraction is particularly effective and permits the shop to be maintained in a permanent state of cleanliness.

Nickel Plating

Electroplating is carried out on "Pernix" trains, fitted with semi-automatic handling gear. They comprise: one nickelplating set; one cadmiumplating set; and one silverplating set. In nickelplating the series of operations carried out is as follows: degreasing coppering; rinsing; hydrochloric scouring; rinsing; rinsing; nickelplating rinsing; rinsing; and hot rinsing. The handling operations are illustrated in Fig. 2.

The equipment is charged with objects at the fixing end, which are carried along by a conveyer chain to the starting point. In Fig. 2, the conveyer equipment is shown carrying eight covers engaging with the chain which draws it along over its roller track from which it is suspended by means of pivoting rollers. When the chain leaves the truck, the latter is on an inclined plane which takes it by gravity to the starting end of the set of troughs. The pneumatic-lifting tackle, of which there are two units in this plant, are mounted in trucks driven mechanically. They circulate along a roller track consisting of two girders fitted above the troughs in the line of the train.

The truck movement is obtained from a cable moving continuously at slow speed, which is gripped by a shoe controlled by a lever, actuated by the left hand of the operator (Fig. 2). With his right hand he operates the raising and lowering gear of the pneumatic hoisting tackle. A system of clips adapted to the spindle of the tackle block permits gripping of the racks by means of two "diabolos" fixed upon the cathode bar. Hooked to the tackle at the starting point, the rack moves down to the degreasing-coppering trough. This trough is supplied with current by a converter set comprising a generator of 1,000 amperes at 10 volt. This current is distributed to the anodes by means of a combined longitudinal and transverse system to ensure a good distribution of the lines of current for plating.

The rack is in contact with a transverse rail provided on the side of the operator by means of a clamp of large surface welded to the cathode bar. Due to a high-current density being applied (5–7 amps. per sq. decimetre) a large amount of hydrogen is developed which is exhausted by a suction device clearly shown in Fig. 2. The period of degreasing-coppering is one minute. By rapid handling, which only takes five or six seconds, the rack passes from this decreasing trough to the rinsing trough. At the end of the tackle travel the end of the rack rests upon a rocking

Fig. 2.—The Nickel Plating Plant.

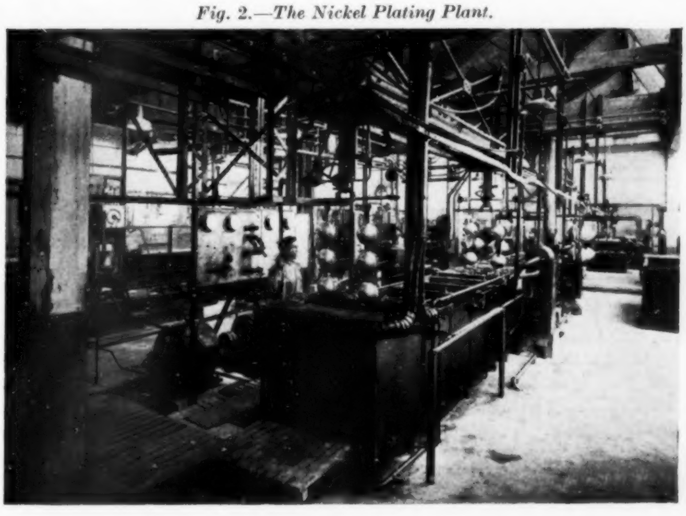


Fig. 3.—The Cadmium plating plant.

Fig. 4.—The continuously moving table in the Cadmium plating shop.

lever and causes a valve to open. A jet of compressed air is thereby blown from a grille and energetically agitates the water so as to improve the rinsing effect. The water is constantly renewed.

In order to ensure perfect adherence, the following operation consists in immersing the rack for a fraction of a minute (12 seconds) in a solution of hydrochlorid acid of 10% strength. A slight corrosion of nicrographical order enables the nickel subsequently to obtain a " hold." This corroding is followed by two rinsing operations. The baths are stirred up by compressed air. While still hooked to the tackle, the rack is introduced in the nickel bath, where it is left for six minutes. The truck is returned to its starting point in order to collect another outfit.

The nickelling electrolyte is of high concentration in metal salts. Its content of metallic nickel is 80 grms. per litre, while its temperature is maintained at 50° C. and its *p*H figure at a value in the neighbourhood of 5·5. Stirring is promoted by compressed air through a grille of lead tubes suitably distributed over the bottom of the trough in order to set up a uniform agitation. Filtration is effected by means of *Pernix* Rotofilters.

The density of current used is 7 amps. per sq. decimetre. The current is supplied by 1,000 amps. 10-volt generator, coupled direct to the motor. It is distributed to the anodes by a combined longitudinal and transverse outfit which ensures a good spread of the lines of current to the objects. The anodes are made of elliptic-depolarised nickel. They are separated behind membranes consisting of filter fabric. Production is ensured by two nickelplating troughs each of which is capable of accommodating three outfits.

The removal of the equipment from the nickelplating troughs is effected by a second workman to whom the second truck is allotted. He also attends to the final operations : rinsing in agitated running water, in hot water, and despatch to the discharging point. The system of semi-automatic handling ensures great flexibility in using the plant. It permits of applying varying periods of electroplating, employing one or two operators, one or two nickelplating troughs, according to the flow of production. Also, it ensures a constant plating quality.

Chromium Plating

Chromium plating is carried out by a set of troughs placed in series. Handling is performed by hand. Nevertheless, the articles are specially placed to ensure perfect contacts. The baths are made up on a basis of chromium salts, the content of metal chromium being 150 grms. per litre, and the proportion SO_4/CrO_2 is maintained in the vicinity of 1/100. The working temperature being 40° C., and the plating period five minutes.

The Cadmium Plating Plant

The cadmium plating plant, shown in Fig. 3, has been provided for the following operations : electrolytical degreasing ; rinsing ; rinsing ; cadmium plating ; rinsing ; rinsing ; brightening ; rinsing ; rinsing ; hot water ; and stove. Handling is effected by means of a very light truck and bracket carrying a pneumatic pulley block. The travel control is mechanical and is obtained by means of friction upon one of the sides of a continuously-moving cable (Fig. 4.)

The loading station comprises a turnstile. The operator brings the truck in front of this station and attaches the outfit charged with objects which are brought along to the degreasing trough. Thence forward, the operations succeed one another in the logical order of the sequence set forth above.

The handwheels for controlling the generator rheostats are within reach of operator's hands, who, from his place on the truck, can readily observe the measuring instruments. A time indicator fixed to the bracket enables him to coordinate the operations to the plan laid down by the works office.

Silver Plating

The silver-plating equipment is placed in parallel with the cadmium-plating plant. The series for operations is as follows : electrolytic degreasing ; rinsing ; rinsing ; amalgam ; rinsing ; rinsing ; silvering ; rinsing ; rinsing acidulated water ; rinsing ; hot rinsing ; and stove. The converter sets, the motor-ventilator sets, and the motor-compressor set are situated between the two lines of troughs. All rinsing is effected by means of water stirred by compressed air. Handling is carried out by the same device as in the cadmium-plating set. This simple device is well adapted to rapid speeds of transfer from one trough to the other. While of remarkable flexibility and precision in handling, great production is ensured by this plant without fatigue to the operators.

Competition of Soviet Metallurgical Plants to produce more Steel

Nearly all the metallurgical plants of the Soviet Union have entered a competition for an All-Union output of 60,000 tons of steel and 45,000 tons of rolled metal a day. Every plant is taking measures to raise its own output to a level that will insure the production of these quantities.

The Kuznetsk Metal Plant which, on September 18, turned out 4,292 tons of steel, and whose blooming mill established an All-Union record by rolling 4,835 tons of metal on the same day, has now pledged itself to produce 4,500 tons of steel and 3,200 tons of rolled metal a day.

Works of Humboldt-Deutzmotoren A.G.

Representative of the many works visited recently by members of the Institute of British Foundrymen, these works have a historic interest, and are briefly described in this article.

THE Deutz Engine Works were founded in 1864 by N. A. Otto and Eugen Langen, as the first works for the construction of gas-engines with a capital of 10,000 thalers. During the first 12 years only atmospheric gas engines of $\frac{1}{4}$ to 3 h.p. capacity were built. In 1872 the enterprise was converted into a joint stock company, and the Deutz Gas Engine works established with a share capital of 300,000 thalers. The grounds of the works covered an area of 600,000 square metres, of which 150,000 square metres were occupied with buildings.

The marine engine assembly shop.

After extensive experiments, Otto created in 1876, the first marketable four-stroke engine, which was developed by him in the beginning of the eighties. Once the four-stroke cycle engine had been established, the internal-combustion engine rapidly became popular for the most varied forms of application. At that time, it was not anticipated that the four-stroke engine would become as useful for road, water and air transport. Mounted upon a truck frame, it served as a locomotive and, after having been fitted with gear-box, as an automobile for road and rail services, not to mention its rapid development as a marine engine while being primarily responsible for the growth of motor traffic and the inception of flying in the air.

As with the atmospheric engine at the Paris World Exhibition of 1867, Otto's new four-stroke engine excited the unstinted admiration of experts at the Paris World Exhibition of 1878. In 1880 Deutz was able to offer the market 10- and 12-h.p. engines, and by 1883 these were already being built for capacities up to 60 h.p.

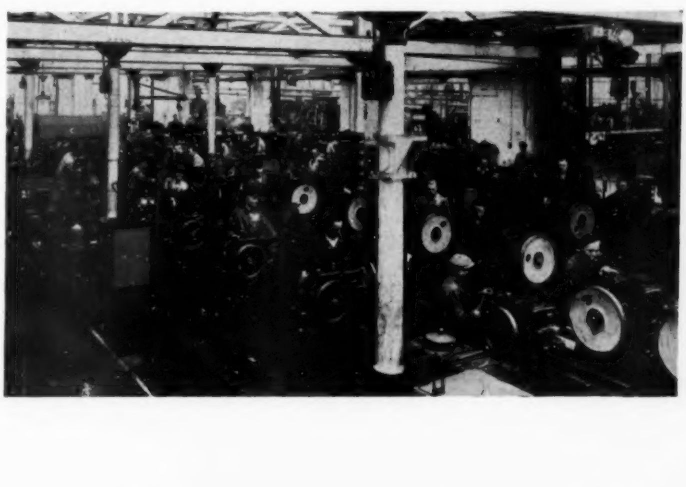
The four-stroke gas engine by Otto and Langen bore the hallmark of ingenious invention, since it solved the problem postulated—to convert thermal energy into external work—not only with a high efficiency or field, but also in a simple manner, and in a form which permitted of general application. In addition to the four-stroke engine, the two-stroke cycle, already inherent in Otto's fundamental patent, was also applied again in practice in 1879. When in 1889 the founders of the Deutz engine works, Otto and Langen celebrated the twenty-fifth anniversary of their firm, they were able to record with deep satisfaction that as many as 30,000 engines developing a total of approximately 100,000 h.p. had already been supplied and were working, distributed throughout the world as prime movers. The staff of 50 workmen had in the meantime risen to 700.

Then, in 1890 was witnessed the development of the motor-locomotive at the Deutz works. In 1896 the first 4-h.p. petrol mining locomotive was built. Due to the great success by which mining locomotives were attended, field, forest, mining, tramway and shunting locomotives were attended, field, forest, mining, tramway and shunting locomotives were then built in brief succession for the various tracks in capacities ranging from four to 100 h.p. Subsequently, the motor-locomotives with Diesel-engine drive were developed for capacities up to 600 h.p. In 1908 Deutz built the first Diesel engine, and in 1912 they marketed the first Diesel engine without a compressor. The further development of the compressorless Diesel engines opened up to them constantly new scopes of application. In 1927 the first vehicle Diesel engine for lorries and omnibuses and boat drive was marketed by Deutz. In addition, 4,000 Diesel-engine tractors were supplied for farming and road purposes. Up to the present, Deutz have applied more than 500,000 engines of six millions horse-power. At present the monthly output is 5,000 engines equivalent to 60,000 h.p. The engines are produced in capacities from two to 2,000 h.p.

As the name "Gas Engine Works" constituted too restricted a designation in the course of development of the power engine, the name was changed in 1921 into "Deutz Engine Works." In 1921, moreover, a combine was entered into with the Oberursel Engine Works under the control of Deutz. In 1924 the Deutz Engine Works entered into a pool with the Humboldt Engineering Works, whereupon an amalgamation was effected between these works in July, 1930, under the joint style of Humboldt Deutz Engine Company (Ltd.), under the management of Deutz. The personnel of the associated enterprises amounts to more than 9,000 workmen and employees.

The present ground area of the Deutz works is 650,000

Assembling and testing small engines ranging from 2–15 h.p.



square metres, whereof 250,000 square metres built over, or including the associated works in Kalk and Oberursel 2,333,524 square metres, whereof 317,334 square metres is covered by buildings. The present working capital amounts to RM. 28,000,000. Deutz have a total of 3,000 machine tools. At the Kalk works motor-locomotives, Diesel tractors, gas-producing plant are built; furthermore, dressing plant for ores and coal, stone crushers, vibrating screens and all kinds of equipment for wet and dry dressing, iron structures, etc. The associated Magirus works in Ulm are building Diesel engines and automotive vehicles of all kinds, fire-extinguishing pumps and motor fire-engines and also other fire-brigade equipment.

Foundries

Although practically the whole of the works was open for inspection, the members visiting these works were especially impressed with the foundries which have quite a large output. The average monthly output of the grey iron foundry is 1,400 tons of castings; these, however, do not supply all the company's needs, and some 600 tons of castings are obtained from outside sources. Although formerly castings up to 40 tons each were made, modern design rarely calls for a casting exceeding 12 tons. The grey-iron foundry is equipped with seven cupolas for the general work, while an electric furnace with a capacity of 2½ tons per hour is used for special high-quality castings, such as cylinders, etc. The non-ferrous foundry is equipped with four non-crucible oil-fired furnaces for melting bronzes, all kinds of red brass and Silumin. A total staff of 750 is employed in these foundries.

Extruded Aluminiums

The facility with which aluminium may be extruded in varied and sometimes intricate shapes, makes it a convenient and economical means of construction in a vast number of applications. This versatility is shown by the large number of sections given in a booklet recently issued by The British Aluminium Co., Ltd., Adelaide House, King William Street, London, E.C. 4. The sections are shown full size and weights are given, which make this booklet useful.

The same Company recently issued an elaborate reprint of a series of articles describing the Lochaber Water Power Scheme. This booklet is both interesting and informative and is excellently produced, the illustrations being particularly good. Copies of these publications are available from the Company.

The Industrial Use of Gas

SOME astonishing figures of the effect of the increasing use of gas on trade revival were given at the recent Silver Jubilee Conference of the British Commercial Gas Association, at Bath. It was shown that gas has already effected a revolution in the steel industry; it is achieving the same in the Potteries; and is beginning to have striking results in the Welsh tinplate industry. The speakers included Mr. W. Clark Jackson, engineer and manager of the Neath Corporation Gas Department; Mr. Alexander Mackay, Chief Engineer of the Stoke-on-Trent Gas Department, and Mr. Ralph Halkett, Junior, assistant general manager of the Sheffield Gas Company.

The introduction of gas-fired furnaces into "The Potteries" has meant that certain ware can be completed in less than 30 hours, whereas two firings in a solid fuel oven would occupy almost two weeks; that the efficiency of the gas-fired tunnel-ovens ranges as high as 70% as against 10% in the ordinary coal-fired ovens; and that practically 100% of perfect ware can be taken from the ovens instead as previously, in many cases, only 30%. At the end of 1932 three ovens were in operation, the gas consumption for the three in that year totalling 28,000,000 cu. ft. There are now 21 ovens in operation, with an aggregate annual consumption of 370,000,000 cu. ft., and a further 11 ovens, now under construction, will be completed before the end of the present year. Some of these ovens are 150 ft. long.

In South Wales lengthy experimental work has resulted in the appointment of a committee to examine a scheme for installing what would practically amount to an entirely separate gas-works plant for providing gas under pressure to the whole of the sheet steel and tinplate works operating within the Neath district. The effect of the scheme would be to give better quality sheets, saving in tin, better conditions for the workmen and a much cleaner atmosphere. It should place the local tinplate industry in a stronger position to withstand competition from abroad and keep the wheels of industry turning more regularly than has been the case during the past twelve to fifteen years.

Over 60% of the sales of gas in Sheffield (nearly 4,000,000,000 cu. ft.) are for industrial purposes. That consumption is increasing in equal ratio to the unexampled development and extension of the undertaking. The South Yorkshire Gas Grid—the only gas grid operating in this country—is operated by the Sheffield Gas Company, and is proving itself a most valuable asset to the local steel industry and is giving to the coking industry a far more optimistic future than looked possible a few years ago.

In the field of research activity it has been proved by practical demonstration that modern applications of gas can reduce very considerably not merely fuel costs, but the general costs of production throughout. In some instances the savings accruing from the proper use of gas, uses determined by recent research, have been as much as three times the cost of the furnace installed in the first year.

Since the establishment of gas development centres, said Mr. H. Stanley Taylor, there have been large increases in the sales of industrial gas, and those increased sales had been spread all over the country. There was no surer sign of trade revival than a general tendency to adopt a high-grade fuel, because fuel was the only raw material that was common to all trades. The industrial demand for gas in the South came very largely from new factories, many of them planted on the fringe of Greater London. This general increase seemed to disprove the common idea that industries were migrating on a large scale from North to South. The crucial factor was rather the planting of entirely new factories in the south.

The August–September issue of The Nickel Bulletin contains some useful information regarding the use of nickel-alloy steels in aircraft engineering. Other informative articles include: Stainless Steels in "Architecture" and "Nickel Cast Iron in the Chemical Industries," in addition to the regular features. Copies may be obtained from The Bureau of Information on Nickel, Thames House, Millbank, London.

Safety in the Metal Industries

Facilities to reduce risks should be provided by the management, and their proper use is a responsibility of the foremen and chargemen.

RISKS of various kinds are experienced in the metal industries, and in his recent presidential address before the Birmingham Metallurgical Society, Mr. E. A. Bolton dealt with a number encountered in the non-ferrous industry. The processes he considered were those in which raw materials were converted into finished rod, strip, sheet, etc. The greatest care is required in the stacking of raw materials and in the proper use of all handling appliances. Regular attention to the maintenance of factory ways, roads and floors eliminate many a source of danger. This is the responsibility of the management, but the proper use of these facilities is the responsibility of the foremen and charge-hands. Often, ingots or plates are too large for charging into the furnace or crucible and cutting has to be carried out on some form of guillotine or crocodile shears. The obvious hazard here is loss of fingers, usually through attempting to cut small pieces on large machines, though injury may be caused through the kicking of larger pieces which are not properly held for cutting. Cuts of a more or less serious character can occur through the careless handling of various kinds of loose scrap. Scrap metal was often dirty and cuts of a minor character can easily become serious, owing to septic conditions setting in.

As soon as the melting stage is reached, several new types of risk arise. Some of these which are less obvious may entail serious consequences, but are calmly taken by operatives, familiarity breeding contempt. The explosive action of the conversion of water into steam through contact with molten metal can have the most serious results, yet it was quite common practice for damp scrap to be thrown into molten metal. Scrap metal should be stored under cover, but where scrap is necessarily damp, it should be handled with great care, every effort being made to dry it by pre-heating. Tube scrap is particularly liable to give trouble in that respect.

Supervision of the melting procedure should be keen to limit dangers involved, and during the pouring of the metal care should be taken against the danger of splashing, the most prevalent cause being the use of damp moulds. After casting, whether in the form of billet, intended for rolling or extrusion, or in the form of strip, it is necessary to remove the gate end, and this may be done by means of a power-driven saw or guillotine. In the former case the operator's eyes should be guarded from flying sawdust, while in the latter case it is necessary to ensure that the ingot is properly held during cutting, otherwise the back end may kick up as the blade descends, possibly trapping the man's hand against the frame of the machine. Blades not properly set may leave a burr on the ingot which would have the keeness of a razor or the point of a needle.

In the process of cold rolling, there is a right and wrong way of inserting the strip into the breaking-down rolls. The operator should stand behind his strip, otherwise there is a possibility of it skidding sideways in the rolls and crushing his body against the roll frame. This is particularly liable to happen in the early stages if the surface of the ingot is wet or greasy, and fatalities have resulted from this cause. If, on the other hand, the man is behind his strip, he has room to jump away in the event of a skid. The difficulty is obviated with modern plant having mechanical facilities. The chief risks in the later stages of cold rolling were cuts on the hands and arms from the sharp edges of the rapidly moving strip. Modern coilers upon fast mills were of the automatic pick-up type and should not give rise to accidents.

Annealing may be carried out with electrical, gas, coal or oil-operated plant, and no special forms of risk attached to this operation, especially if proper regulations were carried out during lighting up. If they are not there may be a danger of a serious explosion. Annealing is usually followed by pickling, which involves the use of acids. The utmost care must be maintained in the storage, conveyance and handling of strong acid in order to avoid burns, and one spot of acid on the eye may cause complete loss of sight. On the other hand, frequent contact with weak acid could cause painful sores on the hands termed "acid holes."

Strip is often rolled in multiples of the width required by the user, and it became necessary for it to be slit to its final width by rotary cutters. This shearing operation is a prolific cause of minor injuries upon the hands and arms of the shearers, who are often boys. Their inexperience and high spirits often result in the casualities mounting to a high figure, and it is not uncommon for youths to exhibit their scars with great pride. Hot rolling had much in common with cold rolling, the additional risk being that the metal was hot, and therefore more awkward to handle, giving risk of burns.

A diversity of methods exists for the production of wire, and it is therefore impossible to generalise. If the first stage consisted of the hot rolling of a billet to form wire rod, the billet would first be rolled backwards and forwards through the grooves of a three-high mill. There is great need for alertness here as the bar elongated very rapidly as its cross-section is reduced at each pass, although the actual rolling speed may not be very great. From the three-high mill the rod passes to a quick-running train of mills placed side by side. Here the rod is looped backwards and forwards until it emerges from the last set in readiness for the coiler. The handling of the rapidly moving rod and the insertion of the leading end into the rolls calls for considerable skill and dexterity. If, through any hitch, any time is lost, the rod loses temperature and becomes very hard and springy. The loops may then become dangerously active, tending to fly about the mill floor, and very serious accidents have happened through men's feet becoming entangled in the loops of hot rod.

Extrusion processes introduce several new types of risks. During the actual extrusion, the whole system is in a state of great internal pressure, and unless proper screening is provided, there may be accidents from the bursting of high-pressure pipes, and from flying fragments of broken tools and dies. The composition of the billet must be such that it is completely solid at extrusion temperature.

There are some risks which are peculiar to the manufacture of tubes. In the piercing operation, billets are occasionally shattered and men may be injured by flying fragments of hot metal. In the pickling of hot tubes, there was the danger of acid being blown from the ends of the tubes which were not completely immersed. On the draw-bench, the greatest danger was the breaking of the neck of the bar, in which case the bar may shoot back through the tube and injure the tube drawer.

From a consideration of the adoption of devices for the safeguarding of the workers, there appears to be three possible methods of attack—namely (1) Complete removal of the risk by the removal of some machine or process (2) The guarding of the machine, furnace or plant, and (3) The direct protection of the individual by the wearing of some protective clothing or appliance. The choice of method to be adopted depends upon the type of risk which existed, the number of men affected and whether the risk was continuous or intermittent. The guiding principle should be that the worker should not be asked to wear any protective appliance unless there is no other reasonable means of overcoming the danger.

Reviews of Current Literature

The Technology of Aluminium and its Light Alloys

THIS book deals very fully with the characteristics of aluminium and its application to industrial arts, with information on manufacture in all forms. The metallography of the metal is fully described, all manufacturing processes are considered including melting, casting, rolling, extrusion, drawing and forging, as well as subsidiary processes such as welding, riveting and surface treatments. The first edition of this treatise was published in 1933, and the fact that this second edition was necessary demonstrades its value. Originally, however, the book was published in the German language, its usefulness was therefore limited, and the present volume, which is translated into English, will be welcomed by a much larger number of interested readers. In addition, this English edition has been revised and attention has been given to British and American products and practice, as well as those of Germany and Switzerland.

The subject is treated in a very lucid manner, and the author gives valuable numerical data and graphs, many diagrammatic and photographic illustrations, a useful list of commercial alloys with their properties and an unusually extensive bibliography. Some indication of the scope of this book will be gathered from a synopsis of the contents which include the production of aluminium ; theory of alloys ; alloys of commercial importance ; properties and methods of testing ; furnace operations ; hardeners ; casting ; rolling ; extrusion ; forging ; presswork and spinning ; wire-drawing ; welding and soldering ; riveting ; machining ; powder manufacture ; surface treatment ; design considerations ; and fields of application. It is doubtful whether any book so far published on aluminium gives so much concise information as this book.

The translation from the second German edition into English, a very difficult task, has been amirably done, and even many who are familiar with the German language, and possess one of the German editions, will welcome this translated edition.

By Dr. ING. ALFRED VON ZEERLEDER, and translated into English by A. J. Field. Published by the Nordeman Publishing Co., Amsterdam ; Agent for United Kingdom and British Empire, Crosby Lockwood and Son, Ltd., Stationers' Hall Court, London, E.C. 4. Price : 21s. net.)

Flotation Plant Practice

As is generally known the flotation process is a common method of extracting minerals from certain classes of ores, and it is a very efficient process. The flotation plant usually comprises one stage in the series of operations for extracting the metallic contents of an ore ; it receives the crude ore and delivers one or more concentrates of sufficiently high grade and in suitable form, so that the extraction of the metals can commence. The actual process of concentrating the minerals by flotation is therefore only one of a sequence of operations, and a complete plant for the purpose comprises crushing, grinding, flotation, concentrate filtration, and tailing disposal sections. It is these operations and the machines involved with which the author is primarily concerned in this book. The information given is based on a series of lectures by the author on modern flotation practice, which were designed to give the engineer and student a broad conception of the subject without burdening them with more detail or theory than was necessary.

The author confines himself to standardised methods, and only the principal machines commonly employed in present-day practice are described. A very useful chapter is that which deals with flotation reagents, because the author has given an outline of the principal theoretical factors which govern their application, the object being to assist the reader in understanding the reasons for the employment of specific types of reagents and the methods of using them.

This book is a second edition—the first edition was only published in 1932—and during the intervening period there has been steady progress rather than a radical change in milling methods. This progress has been incorporated in the new edition. The greatest development has been in the flotation of gold ores, and this section has been completely rewritten. Descriptions of a few new machines and circuits of importance have been added, and other matter revised, and the book enlarged.

By PHILIP RABONE, A.R.S.M., D.I.C. Published by Mining Publications Ltd., Salisbury House, London, E.C. 2. Price : 10s. 6d. net.

Standard Methods of Analysis

THE first edition of this book was published in 1933, and it will be familiar to many engaged in the analysis of iron, steel, and ferro-alloys. This, the second edition, has been amplified and revised. The new volume contains 14 additional methods of analysis including the determination of manganese, phosphorus, titanium, copper, aluminium and zirconium in alloy steels, together with the determination of tungsten, molybdenum, vanadium, titanium, and chromium in their respective ferro-alloys. The original text has been thoroughly revised, and in several instances modifications have been introduced. Of particular note are the inclusion of a double zinc oxide separation in the method of determining cobalt and of the altered technique in the analysis of aluminium-silicon alloy. Modifications of other methods are concerned chiefly with the details to be observed in avoiding the effect of interfering elements. The need for pure reagents is emphasised.

The methods detailed in this book are selected standard methods of analysis of iron, steel, and ferro-alloys. No attempt has been made to include short or approximate methods. All the modifications made and the new methods introduced are the result of exhaustive analytical research in the various laboratories of The United Steel Companies Ltd., and may be used with complete confidence.

Published by THE UNITED STEEL COMPANIES LTD., 17, Westbourne Road, Sheffield, 10, England. Price : 4s. 6d. net.

Modern uses of Non-Ferrous Metals

OF the many metallic elements used industrially, iron accounts for more than 90% of the total production ; it is for this reason that a division between ferrous and non-ferrous metals arises. The non-ferrous metals mostly vary between two extremes, such as gold and platinum, which are scarce but easily reduced to the metallic state, to aluminium and magnesium, which are abundant but difficult to reduce. Industrially the non-ferrous metals may be classified as : those used in substantial quantities in the pure state or serving as the base metal for alloys ; and those used essentially as alloying elements. The non-ferrous metals and alloys have a varied application and it is claimed that at least five thousand alloys of different chemical composition are in industrial use, it will be appreciated therefore, that the preparation of this book has been no light task.

This book differs from the majority of technical works in that the various chapters have been prepared by different contributors. The common metals and many minor metals are surveyed, the useful development of metal products in their special fields being described in non-technical language and in narrative style, the object being to give the young engineer a picture of the metal industry as it exists to-day. It is the seventh in a series of books published for the Seeley W. Mudd Fund designed for junior mining and metallurgical engineers. Each metal is discussed by an expert and the information is presented in an interesting form, which makes the book of value not only to young engineers, but especially to those who have in view an engineering career.

Edited by C. H. MATHEWSON, and published for the Seeley W. Mudd Fund, by the American Institute of Mining and Metallurgical Engineers, 29, West 39th Street, New York, U.S.A.

Business Notes and News

Education of Youths

The education of youths has been taken up seriously by the Social Service organisation at the Cumberland branches of The United Steel Companies, Ltd. The policy of the Company is to raise the educational standard required of juvenile recruits and a scheme to bring the recruitment under closer control is at present receiving the attention of the management.

For the young employees of the Cumberland branches of the Company a scheme of further education is in operation in co-operation with the Local Education Authority. In addition to ordinary classes and technical courses, mining and engineering classes are provided at times suitable for shift workers and should a sufficient number of shift workers desire classes in other subjects, special classes will be instituted. The Company further promotes educational activity amongst their employees by offering special prizes for essays, or reports, concerning the students' own work. A close liaison exists between the Company and the Schools and the Company is kept informed with regard to employees attending courses and the progress they are making.

Imports of Spanish Ore

Considerable difficulty is now being experienced in obtaining Spanish iron ore, especially in view of the warning issued by the Chamber of Shipping of the United Kingdom that the approaches to the ports of Bilbao and Santander are mined. Iron and steel manufacturers who have been accustomed to import Spanish ores are or have made arrangements to obtain suitable supplies from North Africa, Sweden, Norway and other countries. The supplies from Spain have been somewhat irregular for some time, and the position has not improved in recent weeks.

New Soldering Compound

A new tinning compound has been developed which is claimed to overcome all troubles associated with the art of soldering. The trade name of this compound is Soldo. It is stated that it is only necessary to heat the parts to be soldered and then to dip them into the compound when they are immediately tinned. Tests carried out at the National Physical Laboratory have shown that by means of Soldo phosphor-bronze, manganese-bronze, steel and cast iron, were readily tinned; further that joints made on microscopic examination showed interpenetration between metal and tin in all cases. Effective tinning of severely rusted steel and cast iron has also been accomplished by means of this compound.

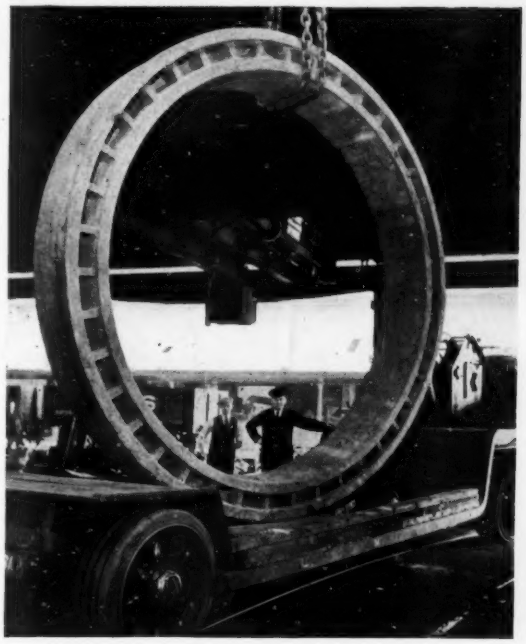
Many experiments have been carried out with the object of testing the efficacy of the compound under difficult conditions, each of which seemed to demonstrate the remarkable cleansing properties of the compound. It is manufactured by the Soldo Co., London, and has been adopted by many leading firms.

World Tin Consumption

Statistics given in the September issue of the *Hague Statistical Bulletin* of the International Tin Research and Development Council, show that the world's apparent consumption of tin in the year ended July, 1936, totalled 152,168 tons, against 129,101 tons in the preceding year. The corresponding production statistics were 162,183 tons and 121,366 tons, respectively. World consumption in the month of July, 1936, was 13,832 tons, against 12,328 tons in the previous month and 12,092 tons in July, 1935.

Comparing the twelve months ended July, 1936, with the previous twelve months, world consumption showed an increase of 17·9%. It is noteworthy that decreases of 16·1% and 8% are recorded for Germany and Spain, respectively, but most countries showed substantial increases, including the U.S.A. 33·6%, France 13·9%, U.S.S.R. 25·1%, Italy 20·3% and Japan 19·0%. Among the smaller consuming countries, the following showed notable percentage increases: Canada 17·4%, Czechoslovakia 36·9%, Poland 43·9%, India 12·8% and Switzerland 14·1%.

World production of tinplate in the year ended July, 1936, reached a new record of 3,363,000 tons, against 3,078,000 tons in the previous year. The former figure represents an increase of 8·8% over the production in the calendar year 1929. The quantity of tin used in the manufacture of tinplate in the year ended July, 1936, is given as 54,700 tons, against 50,200 tons in the previous year.



An Unusual Steel Casting

The accompanying illustration shows an exceptionally large steel casting recently made at the Grimesthorpe foundry of English Steel Corporation, Ltd., Sheffield. The casting is a tyre support for a "Vickers" rotary cement kiln; it has an outside diameter of 14 ft. 7 in. and in the rough state weighs 17 tons.

Certain difficulties were presented in its transport from Sheffield to Barrow-in-Furness because of its diameter. An eight-wheeled bogie wagon was used and special permission to pass through all large towns *en route* was necessary from the Police and local Road Authorities.

Stewarts and Lloyd's Project

A big programme of development at Stewarts and Lloyds' Corby (Northamptonshire) works is foreshadowed by a circular sent out to the company's shareholders recently.

By agreement with the company, Lancashire Steel Corporation is to build and equip a new precision-type bar mill of the latest type at Corby, and will for a long period of years act as a guaranteed outlet for a large tonnage of Stewarts and Lloyds' semi-finished material.

Some Shipbuilding Orders

Three motor vessels, each of about 9,500 tons deadweight have been ordered by the Commonwealth and Dominion Line, Ltd., London, from north-east coast shipbuilders. Two are to be built at Sunderland, one by Messrs. W. Doxford and Sons, Ltd., and the other by Messrs. Joseph L. Thompson and Sons, Ltd., and the third on the Tyne by Messrs. Swan, Hunter and Wigham Richardson, Ltd.

Cost of Gas Production

Reference was made to the remarkable developments in the commercial side of the coal industry in recent months, by Mr. J. Corrigan, at a recent meeting of the North of England Gas Managers' Association, which, he said, has presented an entirely new set of conditions before the gas industry. It is faced with the prospect of having to pay increased prices far above all previous calculations and representing as much as 20% basic increase. Public utilities have in the past been freely accused of taking undue advantage of the conditions of the coal industry, but such a complaint cannot be levelled at the gas industry, since any benefits that have accrued have been passed on to the consumer in the form of cheaper gas.

Discussing the definite prospect of higher production costs, Mr. Corrigan expressed the opinion that the problem would have to be faced from an entirely new angle, and they could not assume their old placidness and say, "Pass it on to the consumer." Competitive conditions necessitated very careful consideration before making a decision.

MARKET PRICES

ALUMINIUM.

98.99% Purity		£100	0	0

ANTIMONY.

English	£68	0	0
Chinese	56	0	0
Crude	26	10	0

BRASS.

Solid Drawn Tubes	lb.	10d.
Brazed Tubes	„	1/-
Rods Drawn	„	9d
Wire	„	8d.
*Extruded Brass Bars	„	4¾d.

COPPER.

Standard Cash	£41	2	0
Electrolytic	45	10	0
Best Selected	44	5	0
Tough	44	0	0
Sheets	72	0	0
Wire Bars	45	15	0
Ingot Bars	45	15	0
Solid Drawn Tubes	lb.	11d.	
Brazed Tubes	„	11d.	

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	3	1½
‡Ferro Tungsten	„	0	3	0
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2-4% Carbon, scale 11/- per unit	ton	29	15	0
NOMINAL: 4-6% Carbon, scale 7/- per unit	„	22	7	6
NOMINAL: 6-8% Carbon, scale 7/- per unit	„	21	12	0
NOMINAL: 8-10% Carbon, scale 7/- per unit	„	21	12	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/0 per unit	„	33	0	0
Guar. max. 1% Carbon, scale 12/6 per unit	„	36	0	0
§Guar. max. 0·5% Carbon, scale 12/6 per unit	„	37	10	0
‡Manganese Metal 97-98% Mn.	lb.	0	1	2
‡Metallic Chromium	„	0	2	5
§ Ferro-Vanadium 25-50%	„	0	12	8
§ Spiegel, 18-20%	ton	7	10	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	6	5	0
20/30% basis 25%, scale 3/6 per unit	„	9	0	0
45/50% basis 45%, scale 5/- per unit	„	12	0	0
70/80% basis 75%, scale 7/- per unit	„	17	6	6
90/95% basis 90%, scale 10/- per unit	„	28	17	6
§ Silico Manganese 65/75% Mn., basis 65% Mn.	„	12	5	0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20-25%	ton	22	0	0
§ Ferro-Molybdenum, Molyte	lb.	0	4	6
§ Calcium Molybdate	„	0	4	2

FUELS.

Foundry Coke—				
S. Wales	—	1	10	0
Scotland	—	1	10	0
Durham		1	4	6
Furnace Coke—				
Scotland	—	1	5	0
S. Wales	—	1	5	0
Durham	—	1	1	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£60	10	0
*Commercial Ingots	45	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards.. lb.	0	0	9
*Cored Bars „	0	0	11

MANUFACTURED IRON.

Scotland—			
Crown Bars, Best	£10	5	0
N.E. Coast—			
Rivets	10	10	0
Best Bars	10	2	6
Common Bars	9	5	0
Lancashire—			
Crown Bars	10	10	0
Hoops........£10 10 0 to	12	0	0
Midlands—			
Crown Bars	10	10	0
Marked Bars	13	0	0
Unmarked Bars...... from	7	5	0
Nut and Bolt Bars....... £8 10 0 to	9	0	0
Gas Strip	10	12	6
S. Yorks—			
Best Bars	10	15	0
Hoops ...... £10 10 0 to	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	9d.
*Cored Bars	„	11d.
†Strip	„	11½d.
†Sheet to 10 W.G.	„	1/-
†Wire	„	1/0¾
†Rods	„	11d.
†Tubes	„	1/2½
†Castings	„	1/0½

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£4	5	6
Foundry No. 1	4	1	6
„ No. 3	3	19	0
N.E. Coast—			
Hematite No. 1	4	5	6
Foundry No. 1	3	17	6
„ No. 3	3	15	0
„ No. 4	3	14	0
Silicon Iron	—		
Forge	3	14	0
Midlands—			
N. Staffs Forge No. 4	3	17	0
„ Foundry No. 3	4	0	0
Northants—			
Foundry No. 1	4	3	0
Forge No. 4	3	14	6
Foundry No. 3	4	0	0
Derbyshire Forge	3	17	0
„ Foundry No. 1	4	3	0
„ Foundry No. 3	4	0	0
West Coast Hematite	4	5	6
East „ „	4	5	6

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0.015, of phosphorus 0.025.
Per English ton .. .. .. Kr. 115
Billets, single welded, over 0.45 Carbon.
Per metric ton.. .. .... Kr. 255-325
Per English ton .. £13 7 6/£17 0 0
Wire Rods, over 0.45 Carbon.
Per metric ton Kr.305-355
Per English ton £16 0 0/£18 12 6
Rolled Martin iron, basis price.
Per metric ton Kr.200-220
Per English ton.. £10 10 0/£11 10 0
Rolled charcoal iron, finished bars, basis price.
Per metric ton Kr.310
Per English ton £16 5 0
f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£33	0	0
„ Braziery	30	0	0
„ Wire	—		
Brass	20	10	0
Gun Metal	31	0	0
Zinc	8	10	0
Aluminium Cuttings	74	0	0
Lead	16	10	0
Heavy Steel—			
S. Wales	3	5	0
Scotland	2	17	6
Cleveland	2	17	6
Cast Iron—			
Midlands	2	12	6
S. Wales	2	17	6
Cleveland	3	5	0
Steel Turnings—			
Cleveland	2	0	0
Midlands	2	0	0
Cast Iron Borings—			
Cleveland	1	7	6
Scotland	1	17	6

SPELTER.

G.O.B. Official	—		
Hard	£11	15	0
English	15	2	6
India	12	15	0
Re-melted	13	10	0

STEEL.

Ship, Bridge, and Tank Plates			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland ..	8	10	0
„ „ (Marine) „ ..	—		
„ „ (Land), N.E. Coast	8	10	0
„ „ (Marine) „	8	17	6
Angles, Scotland	8	7	6
„ North-East Coast	8	7	6
„ Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	10	0
Light Rails ......£8 10 0 to	8	15	0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic ....£6 17 6 to	7	2	6
Medium Basic..£6 12 6 and	7	0	0
Soft Basic	5	10	0
Hoops..........£9 10 0 to	9	15	0
Manchester			
Hoops..........£9 0 0 to	10	0	0
Scotland, Sheets 24 B.G.	10	10	0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten ..	lb.	2/-
Finished Bars 18% Tungsten ..	„	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	„	3d.
Under ¼ in. to $\frac{1}{8}$ in.	„	1/-
Round and Squares 3 in.	„	4d.
Flats under 1 in. × ⅜ in.	„	3d.
„ „ ¼ in. × ⅛ in.	„	1/-

TIN.

Standard Cash	£200	0	0
English	200	0	0
Australian	199	15	0
Eastern	201	5	0
Tin Plates I.C. 20 × 14 box	18/9		

ZINC.

English Sheets	£24	10	0
Rods	25	10	0
Battery Plates	—		
Boiler Plates	—		

LEAD.

Soft Foreign	£18	5	6
English	20	5	0

*McKechnie Brothers, Ltd. Oct. 13. † C. Clifford & Son, Ltd., Oct. 13. ‡ Murex Limited, Oct. 13.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.
§ Prices ex warehouse, Oct. 13.